

CONTRIBUTIONS
FROM THE
CUSHMAN FOUNDATION
FOR
FORAMINIFERAL RESEARCH

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION FOR FORAMINIFERAL RESEARCH

Editor

Hans E. Thalmann

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
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108. UPPER CRETACEOUS ORBITOIDAL FORAMINIFERA
FROM CUBA

PART II. *Vaughanina* Palmer 1934

P. BRONNIMANN

Gulf Oil Corporation, Habana

In Part I of the present studies of Cuban Upper Cretaceous orbitoidal Foraminifera (Bronnimann, 1954), the genus *Sulcorbitoides*, genotype *S. pardo*, was described. *Vaughanina* Palmer, 1934, is related to *Sulcorbitoides* by the sulcoperculinoid juvenarium and by the two alternating systems of vertical radial plates. Annular walls in *Vaughanina*, however, clearly differentiate the two genera.

Vaughanina is structurally more complex and stratigraphically younger than *Sulcorbitoides*. Both genera are here interpreted as having lived at different times and being indirectly related off-shoots from *Sulcoperculina* Thalmann, 1938.

The family relationship of *Vaughanina* has not yet been clarified. As in the case of *Sulcorbitoides*, it is provisionally assigned to the subfamily Pseudorbitoidinae M. G. Ruten, 1935, of the family Orbitoididae Schubert, 1920. *Vaughanina* is represented by two species, *V. cubensis* Palmer, 1934, the genotype, and *V. barkeri* Bronnimann, n. sp.

Acknowledgments.—The author is indebted to Gulf Oil Corporation for the use of the facilities of the Geological Laboratory in Habana; to Shell Development Company, Houston, for the permission to include the description of *Vaughanina barkeri*, n. sp.; to G. Pardo, Habana, for the drawing of the structure model of *Vaughanina*; to N. K. Brown, Jr., Habana, for reading and discussing the manuscript; and to R. Wright Barker, Houston, for the photographs of *Vaughanina barkeri*, n. sp.

The original material is in the author's collection and in those of Cuban Gulf Oil Company, Habana.

ORBITOIDIDAE Schubert, 1920

PSEUDORBITOIDINAE M. G. Ruten, 1935

Genus *Vaughanina* Palmer, 1934

Genotype: *Vaughanina cubensis* Palmer, 1934

Emended definition.—The lenticular test is divided into an equatorial layer and two lateral layers. A peripheral ringlike zone of the equatorial layer, or flange is exposed. The surface of the flange contains numerous radial plates which project slightly over the edge of the test, forming a delicate pectinate outline. The juvenarium is bilocular and shows a uniserial peri-

embryonic spiral of 5 to about 27 chambers. It is asymmetric in vertical section and trochospiral. A rudimentary peripheral sulcus characterizes the early whorls. The neanic part of the equatorial layer is subdivided into annular chambers formed from low elongate chambers disposed around the periembryonic spiral. The equatorial layer is not divided into horizontal layers. Two alternating systems of vertical radial plates project from the roof and from the floor into the equatorial layer. These systems are separated by a narrow median gap. Large radial stolons, one of which is between two radial plates, pierce the annular walls near the floor and roof of the equatorial layer. Stolons and fine pores connect the equatorial layer with the lateral chambers which are arranged in regular tiers. In the adult these tiers are separated by pillars and their walls pierced by stolons and fine pores.

Occurrence.—Cuba; Florida; Mexico; Guatemala; Venezuela; possibly Bonaire, D.W.I.

Vaughanina cubensis Palmer

Plate 16, figures 1-11; plate 17, figures 1-6;
plate 18, figures 4-10. Text figures 1-9

1932. *Pseudorbitoides israelskii* VAUGHAN and COLE, Proc. Nat. Acad. Sci., vol. 18, p. 615, pl. 2, fig. 7 (not figs 1-6).

1934. *Vaughanina cubensis* PALMER, Mem. Soc. Cubana Hist. Nat., vol. 8, p. 241, pl. 12, fig. 5; pl. 13, figs. 2, 4; text-figs. 2, 3.

1936. *Vaughanina cubensis* PALMER, RUTTEN, Geog. geol. Mededeel., Rijksuniv. Utrecht, no. 11, p. 39, pl. 22, fig. 2.

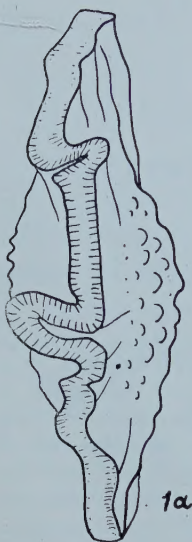
1937. *Vaughanina cubensis* PALMER, VOORWIJK, Proc. Kon. Akad. Wetensch. Amsterdam, vol. 40, p. 197, pl. 3, figs. 1, 2, 4, 5, 7.

1943. *Vaughanina cubensis* PALMER, VAUGHAN and COLE, Jour. Paleont., vol. 17, p. 98, pl. 17, figs. 3, 4; pl. 18, figs. 1-10.

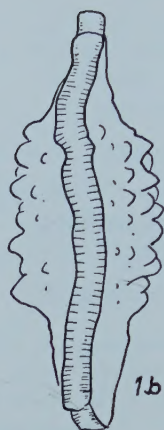
1944. *Vaughanina cubensis* PALMER, COLE, Bull. Florida Geol. Surv., no. 26, p. 57, pl. 3, figs. 11; pl. 21, figs. 6, 7.

1945. *Vaughanina cubensis* PALMER, KEIJZER, Geog. geol. Mededeel., Rijksuniv. Utrecht, ser. 2, no. 6, p. 212, pl. 7, fig. 81.

1947. *Vaughanina cubensis* PALMER, COLE and BERMU-



1a



1b



2



3a



3b



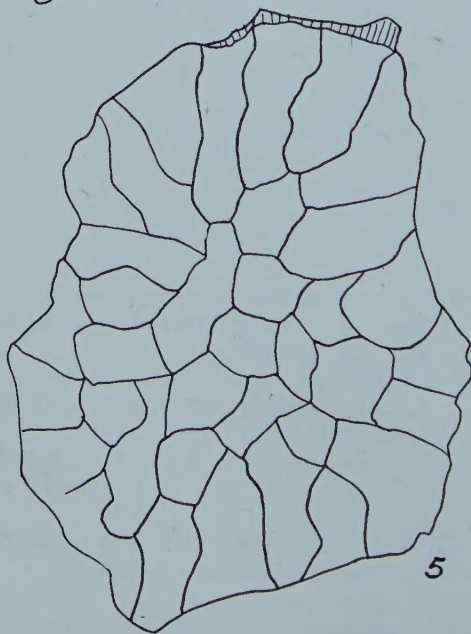
4a



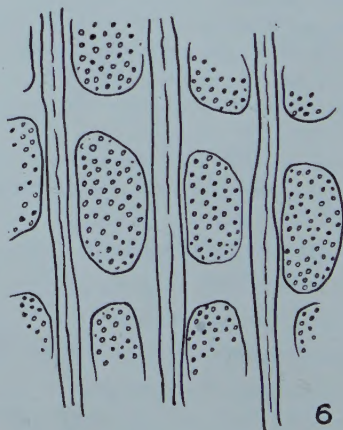
4b



4c



5



6

TEXT FIGURES 1-6

DEZ, Bull. Amer. Paleont., vol. 31, no. 125, p. 11, pl. 3, figs. 10-13.

1948. *Vaughanina cubensis* Palmer, de CIZANCOURT, Bull. Soc. Géol. France, 5^e sér., vol. 18, p. 670, pl. 24, figs. 1-4.

1952. *Vaughanina cubensis* Palmer, BERMUDEZ, Venezuela Ministerio de minas e hidrocarburos, Bol. Geol., vol. 2, no. 4, p. 132, pl. 29, figs. 1-4.

Type locality.—Palmer Station 1214: approximately 1 km. W. of Central San Antonio, on the railroad to Central Hershey, Habana Province, Cuba. Age: Paleocene. *V. cubensis* is apparently redeposited here from the Upper Cretaceous beds.

Lectotype.—D. K. Palmer (1934) designated cotypes but not a holotype. One of her cotypes, the specimen illustrated by fig. 5 on pl. 12, is herewith designated as lectotype, deposited in the Scripps Institution of Oceanography, La Jolla, California.

1. Occurrence.—*V. cubensis* is common and widely distributed in the Cuban Maestrichtian. Outside Cuba it has been recorded from the subsurface Upper Cretaceous of Florida (Cole, 1944) and from Venezuela (Cizancourt, 1948). It also occurs in Guatemala. The vertical section of an orbitoid from an Upper Cretaceous limestone cropping out in southern Petén, Guatemala, determined by Vaughan and Cole (1932, p. 615, pl. 2, fig. 7) as *Pseudorbitoides israelskyi* Vaughan and Cole, is here referred to *V. cubensis* (see synonymy). MacGillavry (1937, p. 27) observed in a thin section of a rudist limestone from Guatemala which contained *Barettia monilifera* Woodward, *Sulcoperculina dickersoni* (Palmer) and an orbitoid identified as *Pseudorbitoides israelskyi* Vaughan and Cole. According to MacGillavry, however, this orbitoid belongs to the genus *Vaughanina*. A doubtful occurrence of *Vaughanina* has been reported by Keijzer (1945, p. 212) from the Upper Cretaceous Rincon formation of Bonaire, D.W.I. Barker and Grimsdale (1937, p. 173)

mentioned *V. cubensis* also from the Upper Cretaceous of the state of Veracruz, Mexico. Photographs of three oriented thin sections, kindly donated by R. Wright Barker, are reproduced in figs. 1-3, pl. 18, of this paper. Barker and Grimsdale's form is undoubtedly a new species of *Vaughanina*, herein described as *V. barkeri* Bronnimann, n. sp.

2. Age.—Palmer Station 1214, the type locality of *V. cubensis*, was placed by D. K. Palmer (1934, p. 242, 243) in the Upper Cretaceous. This age assignment seems to be supported by the associated *Orbitoides browni* (Ellis), *Asterorbis macei* Palmer, *A. rooki* Vaughan and Cole, and *?Meandropsina rutteni* Palmer. In the annotation to Palmer Station 1214, R. H. Palmer (1948, p. 72) reported abundant Foraminifera and one specimen of the echinid *Lanieria* in a conglomerate boulder and in the matrix from this locality. Re-sampling of Palmer Station 1214 (see Bronnimann Stations 25 to 28) has shown that the Cretaceous fossils are redeposited in a Paleocene boulder bed. Thus, the above assemblage of larger Foraminifera is probably heterogeneous. Rutten (1936, pp. 36, 39), Thiadens (1937a, p. 40) and Albear (1947, p. 80) noted *V. cubensis* in the Upper Cretaceous Habana formation of Santa Clara (Las Villas) Province, and Camagüey Province, Cuba. Thiadens (1937a, p. 43) listed the following Maestrichtian association: *Asterorbis*, *Lepidorbitoides*, *Pseudorbitoides*, *Orbitoides*, *Sulcoperculina*, *?Archaias* [= *?Meandropsina*] *rutteni* Palmer, globigerinids, Radiolaria, rudists, corals and echinids. In his earlier paper on the rudists of southern Santa Clara, Thiadens (1936a, p. 1013), recorded *Lepidorbitoides*, *Orbitoides* and *Vaughanina* from the same locality as the Maestrichtian rudist *Praebarretia sparcilirata* Whitfield. MacGillavry (1937, pp. 27, 92) observed in Camagüey Province, *V. cubensis* and *Sulcoperculina dickersoni* (Palmer) in the same rock as the Maestrichtian rudist *Parastroma*

EXPLANATION OF TEXT FIGURES 1-6

TEXT FIGURE 1a, b *Vaughanina cubensis* Palmer

Palmer Station 1214. Appr. 32 \times . Side view of two specimens, one (a) with deeply plicate peripheral flange.

TEXT FIGURE 2 *Vaughanina cubensis* Palmer

Brown Station 30011. Appr. 103 \times . Surface of HCl-etched specimen showing lateral chambers adjoining peripheral flange and meshwork of rectangular "chamberlets."

TEXT FIGURE 3a, b *Vaughanina cubensis* Palmer

Brown Station 30011. Appr. 103 \times . Side view of peripheral flange with radial plates, median gap, annular wall and large radial stolons (stippled).

TEXT FIGURE 4a-c *Vaughanina cubensis* Palmer

Palmer Station 1214, Gravell Station 7480 and Brown Station 30011. Appr. 103 \times . Schematic drawing of the radial plates in adult specimens. The plates are long, thin, and start to develop bifurcations and irregularities.

TEXT FIGURE 5 *Vaughanina cubensis* Palmer

Gravell Station 7480. Appr. 103 \times . Surface of young specimen, showing the arrangement of the lateral chambers. Those at the periphery are elongate and with the long axis perpendicular to the periphery. No pillars are present in this stage.

TEXT FIGURE 6 *Vaughanina cubensis* Palmer

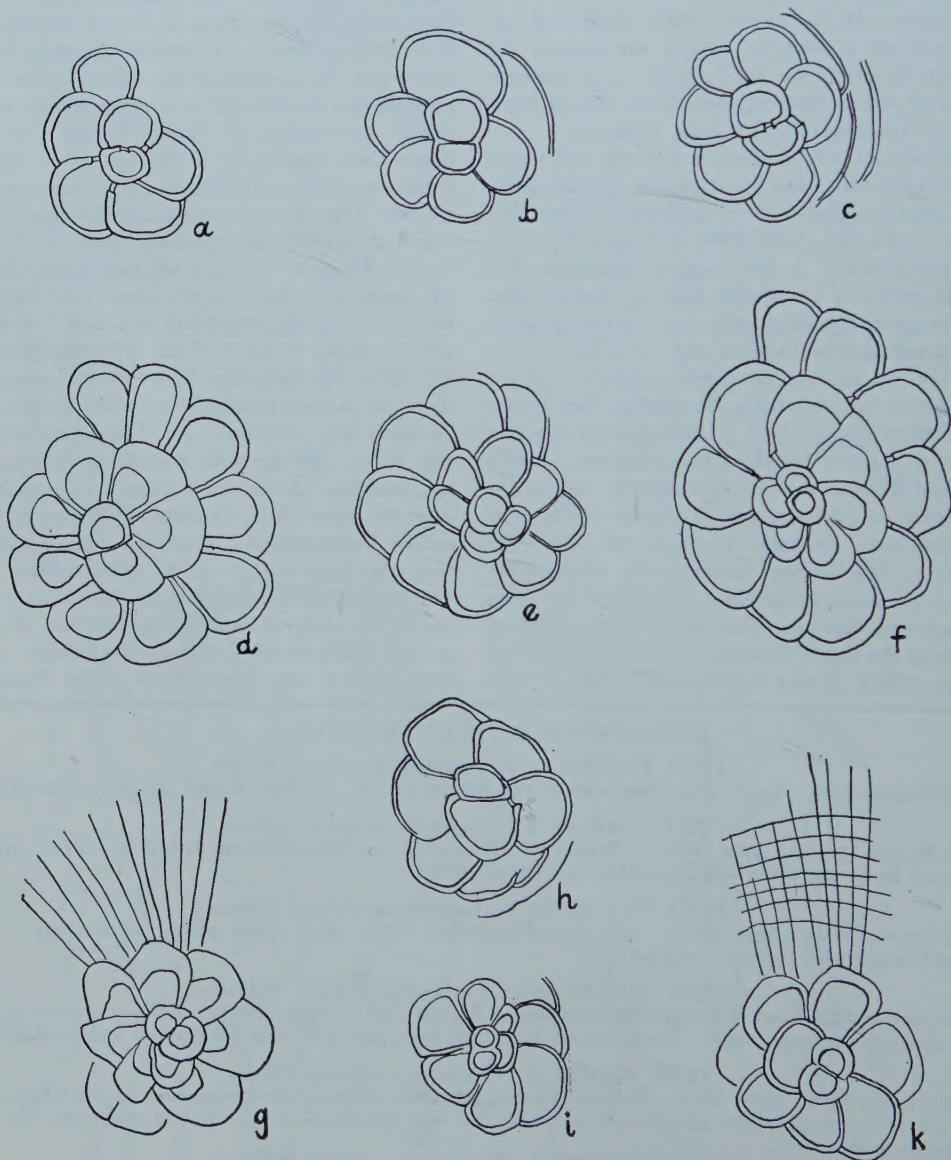
Brown Station 30011. Appr. 417 \times . Surface of peripheral flange exposing radial plates composed of two thin lamellae. Fine pores in the walls of the rectangular "chamberlets."

guitarti (Palmer), and from a different locality, also in Camagüey Province, *V. cubensis* and *Titanosarcolites giganteus* (Whitfield). MacGillavry regards *V. cubensis* as an index fossil for the Maestrichtian.

Voorwijk (1937, p. 191) listed typical Upper Cretaceous foraminifers from several localities near Habana, namely, *Vaughanina cubensis*, *Globotruncana lapparenti* s.l., *Globotruncana havanensis* Voorwijk, *Planoglobulina acervulinoides* (Egger), *Sulcoperculina dickersoni* (Palmer), ?*Meandropsina ruttleri* Palmer, *Pseudotextularia varians* (Rzehak), *Pseudogümbelina striata* (Ehrenberg), *Gümbelina globulosa* (Ehrenberg),

and a few more but less important species. *Orbitoides browni* (Ellis) apparently does not occur together with *V. cubensis*. No Paleocene forms are mentioned by Voorwijk.

Cole (1944, p. 57) recorded *V. cubensis* from the Upper Cretaceous of a well (W-336) in Florida at a depth of 2985-3000 feet together with *Pseudorbitoides israelskyi* Vaughan and Cole and *Orbitoides palmeri* Gravell. According to Applin and Jordan (1945, p. 132) the upper member of the youngest Cretaceous beds (Lawson limestone), of peninsular Florida, contain a poorly preserved fauna including *Vaughanina*



TEXT FIGURE 7 *Vaughanina cubensis* Palmer

a-f: Brown Station 30011. g-k: Bronnimann Station 28. All approx. 93X. Different types of nepionic development.

sp., an undescribed rotaloid form, and *Pseudorbitoides?* sp. Cole. The lower member carries a rich orbitoidal fauna of *Asterorbis*, *Lepidorbitoides*, *Sulcoperculina*, but no *Vaughanina*.

Keijzer (1945, pp. 22, 23, 212) regarded *V. cubensis* as an index fossil for the Senonian to Danian-Montian Habana formation of Oriente Province. He found *V. cubensis* associated with *Omphalocyclus macropora* (Lamarck), *Orbitoides browni* (Ellis), *Lepidorbitoides* spp. and *Sulcoperculina dickersoni* (Palmer), a typical Maestrichtian assemblage, but also with *Discocyclina* sp. (Loc. W. 316, Oriente Province, and localities in Pinar del Río Province, listed in table 19, on p. 157 of Keijzer's paper). Thus the range of *V. cubensis* is given as Upper Cretaceous to Danian-Montian. Keijzer's faunal lists are not sufficient to determine whether or not the assemblages from the Danian-Montian are homogeneous. Mixed Upper Cretaceous-Paleocene faunas in which *Orbitoides*, *Vaughanina*, *Torreina*, *Globotruncana*, etc. are believed to be allochthonous, are cited by Bermudez (1950, p. 220). Cole and Bermudez (1947, p. 4) described a predominantly Middle Eocene fauna, which also contains well-preserved *V. cubensis* from Bermudez Station 1266 (cut at Finca "La Coronela," on the road from Habana to Rancho Boyeros). The occurrence of *V. cubensis* in beds of Middle Eocene age was ascribed either to redeposition or to an extension of its life range from the Upper Cretaceous into the Eocene. Redeposition, however, is preferred, and later, Cole and Gravell (1952, p. 711) regarded the presence of Cretaceous to Lower Eocene species in Bermudez Station 1266 as due exclusively to redeposition.

The faunal associations discussed above indicate a Maestrichtian age for *V. cubensis*. All younger occurrences are regarded as allochthonous. In order to obtain information on the age of *V. cubensis* relative to the *Globotruncana* zonation of the Maestrichtian (Bronnimann, 1952), the diagnostic Foraminifera of the following Cuban localities have been determined:

Bronnimann Station 10.

Recent beach-sand, from spit N.W. of Mariel; Pinar del Río Province.

Bronnimann Stations 25-28; Gravell Station 7876.

All stations from one outcrop about 1 Km W. of Central San Antonio on railroad to Central Hershey. N. side of low railroad cut, W. of point where secondary road crosses railroad; Habana Province.

This is the same locality as Palmer Station 1214. Type locality of *Vaughanina cubensis*.

Brown Station 30011.

N.W. corner of Paseo Carlos III and Calzada Belascoain (Padre Varela), in construction pit of the Gran Templo Nacional Mazonico, City of Habana.

Gravell Station 7480.

500 m S.E. of Km. 16.4 of Bahia Honda Road; Pinar del Río Province.

Samples collected at Palmer Station 1214.

Gravell Station 7876.

Vaughanina cubensis is absent. Planktonic species are well represented.

Sulcoperculina dickersoni (Palmer)

Asterorbis spp.

Orbitoides s. s. spp.

Omphalocyclus macropora (Lamarck)

Rugoglobigerina (*R.*) *rugosa rugosa* (Plummer)

Globotruncana lapparenti s. l.

Globotruncana stuarti (de Lapparent)

Globotruncana gansseri Bolli

Globotruncana havanensis Voorwijk

Globotruncana rosetta (Carsey)

Gümbelina globulosa (Ehrenberg)

Gümbelina pseudotessera Cushman

Pseudogümbelina costulata (Cushman)

Pseudogümbelina striata (Ehrenberg)

Pseudotextularia varians (Rzehak)

ostracodes, small gastropods, and pelecypods.

This assemblage appears to be homogeneous; the planktonic species are representative of the Lower Maestrichtian *Globotruncana gansseri* zone.

Bronnimann Station 25.

The fauna is heterogeneous. Cretaceous species, including *Vaughanina cubensis*, *Asterorbis* spp., are redeposited in a Paleocene bed, characterized by well-preserved specimens of *Globorotalia wilcoxensis* Cushman and Ponton var. *acuta* Toulmin.

Bronnimann Station 26.

The fauna is mixed Cretaceous-Paleocene. *Vaughanina cubensis* is abundant and well preserved. The Paleocene species are:

Globigerina stainforthi Bronnimann

Globigerina pseudobulloides Plummer

Globorotalia crassata (Cushman) var. *aequa* Cushman and Renz

Globorotalia sp.

Eouwigierina sp.

Bronnimann Station 27.

Vaughanina cubensis does not occur in the sample from this station. The fauna consists of:

Asterorbis spp.

Sulcoperculina dickersoni (Palmer)

Colomia cretacea Cushman and Bermudez

Globotruncana gansseri Bolli

Globotruncana lapparenti s. l.

Globotruncana stuarti (de Lapparent)

Gümbelina globulosa (Ehrenberg)

Gümbelina pseudotessera Cushman

Pseudogümbelina costulata (Cushman)

Pseudotextularia varians (Rzehak)

Gümbelitra cretacea Cushman

Rugoglobigerina (R.) *macrocephala macrocephala*

Bronnimann

This assemblage appears to be homogeneous and is essentially the same as the one of Gravell Station 7876. Age: *Globotruncana gansseri* zone. *Vaughanina cubensis*, *Orbitoides* and *Lepidorbitoides* have not been recorded.

Bronnimann Station 28.

The sample from this station contains matrix and boulders. The fauna is heterogeneous.

Thin sections of the boulders exhibit well-preserved and abundant Cretaceous species, including *Asterorbis* spp., *Vaughanina cubensis*, and abundant algal debris consisting mainly of branches of *Cymopolia elongata* (Defrance). This alga is known from the Paleocene to the Oligocene and has been reported by Keijzer (1945, p. 179, pl. 6, fig. 87) from the Danian-Montian Cobre formation of Oriente Province. The age of the beds at Station 28 is Paleocene.

Other samples.

Bronnimann Station 10.

From Recent beach sand have been determined, excluding Recent Foraminifera:

Vaughanina cubensis Palmer (common and well preserved)

Sulcoperculina dickersoni (Palmer)

Sulcoperculina cubensis (Palmer)

Sulcoperculina vermunti (Thiadens)

Asterorbis spp.

Omphalocyclus macropora (Lamarck)

"*Borelis*" *floridana* Cole

"*Borelis*" *gunteri* Cole

Globotruncana lapparenti s. l.

Globotruncana stuarti (de Lapparent)

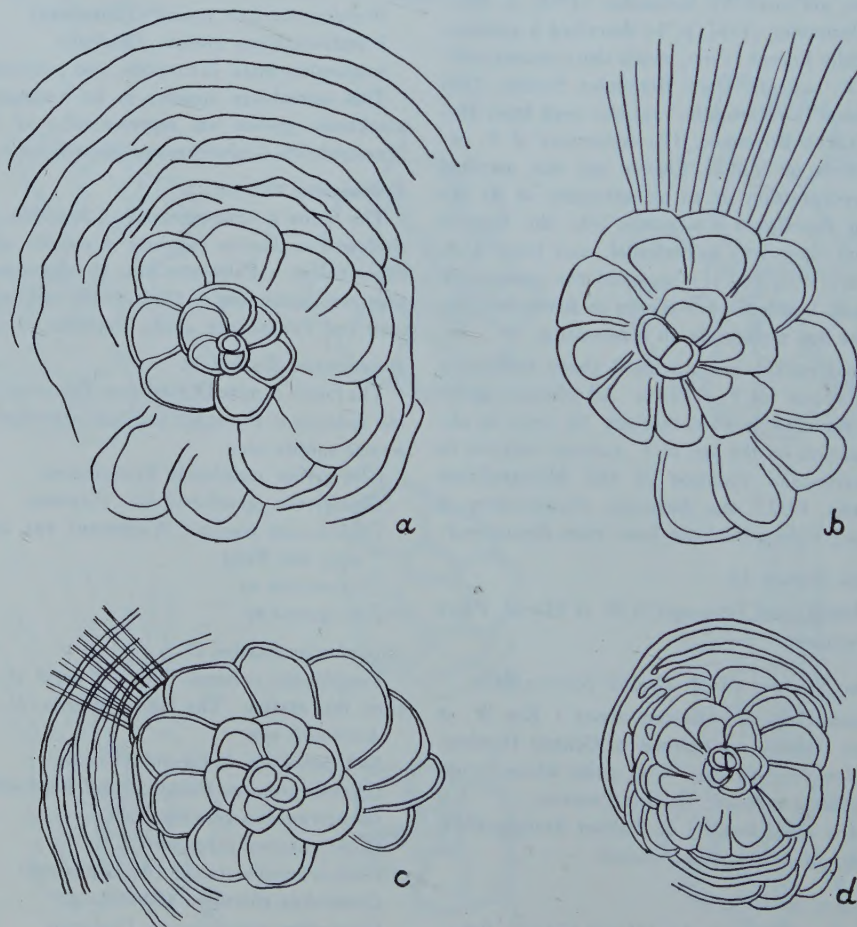
Lockhartia sp.

Dictyoconus sp.

Cuneolina sp.

Gravell Station 7480.

The fauna from this locality is mixed Cretaceous-



TEXT FIGURE 8 *Vaughanina cubensis* Palmer

a-d: Brown Station 30011. Approx. 93× Different types of nepionic development. Sections a, c, and d: showing early arrangement of annular chambers; Section b: in the plane of the radial plates and radial stolons.

Paleocene. Typical Paleocene species are:

"*Borelis*" *floridana* Cole

"*Borelis*" *gunteri* Cole

Boldia sp.

Brown Station 30011.

The well-preserved fauna from this locality contains many orbitoids and abundant planktonic Foraminifera:

Vaughanina cubensis Palmer (abundant)

Torreina torrei Palmer

? *Meandropsina rutteni* Palmer

Sulcoperculina dickersoni (Palmer)

Sulcoperculina vermunti (Thiaden)

Sulcoperculina cubensis (Palmer)

Globotruncana havanensis Voorwijk

Globotruncana mayaroensis Bolli

Globotruncana stuarti (de Lapparent)

Globotruncana contusa (Cushman)

Gümbelina globulosa (Ehrenberg)

Pseudogümbelina palpebra Bronnimann and Brown

Pseudogümbelina excolata (Cushman)

Pseudogümbelina costulata (Cushman)

Pseudogümbelina striata (Ehrenberg)

Pseudogümbelina punctulata (Cushman)

Gublerina robusta de Klasz

Gublerina glaessneri Bronnimann and Brown

Pseudotextularia varians (Rzehak)

Rugoglobigerina (R.) *rugosa rugosa* (Plummer)

Pseudovalvulineria vombensis Brotzen

Stensiöina pommerana Brotzen

This assemblage, characterized by *Globotruncana mayaroensis* Bolli, contains abundant and well-preserved *Vaughanina cubensis*. It is homogeneous and must be assigned to the Middle to Upper Maestrichtian (*Globotruncana mayaroensis* zone), *Orbitoides*, *Omphalocyclus macropora* (Lamarck), *Lepidorbitoides* spp. and *Asterorbis* spp. are absent.

To summarize, *Vaughanina cubensis* appears to be absent in the *Globotruncana gansseri* zone (Gravell Station 7876, Bronnimann Station 27); however, it occurs in the *Globotruncana mayaroensis* zone (Brown Station 30011). Further, *V. cubensis* has been encountered in heterogeneous assemblages of Paleocene and younger age, where it is regarded as redeposited.

3. *Morphologic description*.—The complicated structure of *Vaughanina cubensis* has been studied by Palmer (1934) and by Vaughan and Cole (1943). The morphologic descriptions by these authors differ in several points. An attempt has been made to clarify these divergencies and to present a concept of the structure of this orbitoidal foraminifer free of contradictions. Vaughan and Cole's examination is accompanied by excellent photographs of the exterior and of oriented thin sections. Attention is also called to the photographs of equatorial and lateral layers in Voorwijk's paper (1937). For information on the general appearance of the test, on thin sections of whole specimens and on dimensions, reference is made to these

publications. A model of a portion of the equatorial layer is presented here to facilitate the understanding of the structure of the test (text-fig. 9).

Exterior.

The general aspect of the test is that of a typical lenticular orbitoid. However, the lateral layers cover the equatorial layer only over the center and expose a conspicuous marginal ring of equatorial layer or peripheral flange. Not protected by lateral layers, the flange is easily worn or broken off. The width of the marginal ring is about 0.1 mm in small specimens and about 0.2 mm in large specimens. The thickness of the flange, measured at the periphery, ranges from about 20 microns to 200 microns. Flanges of 200 microns and thicker are rare in our material. Specimens of equal diameter can develop flanges which vary considerably in thickness. The thickness of the flange is possibly a feature of subspecific or varietal significance. The flange is slightly undulate to plicate (text-fig. 1), and rarely deeply notched (Vaughan and Cole 1943, plate 17, figs. 3, 4). Radial lines on the surface of the flange correspond to a system of radially arranged vertical plates. The radial plates project slightly over the edge of the flange and form a finely pectinate outline. Under water or after weak HCl treatment a faint meshwork of rectangular "chamberlets" (text-fig. 2) appears. It is formed by radial plates and annular walls. The annular walls are less distinct on the surface of the flange than the radial plates. The meshwork indicates an internal subdivision of the equatorial layer. It is reminiscent of the chamberlets of *Discocyclina*. Yet, as will be shown later, true chamberlets of the *Discocyclina*-type are not formed in *Vaughanina*. The "chamberlets," as suggested by the meshwork, are longer in radial than in tangential direction, and rather narrow. Their walls are pierced by numerous fine pores and by stolons (text-fig. 6).

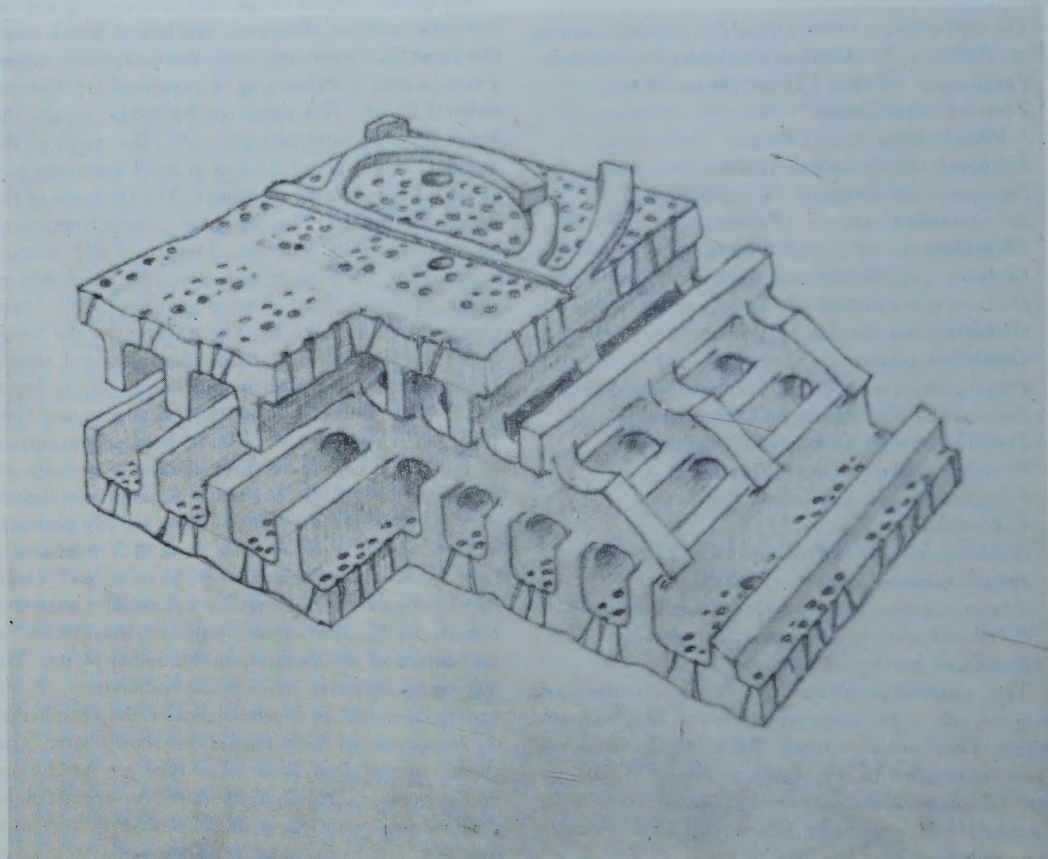
The characteristic surface markings of the exposed equatorial layer and the pectinate outline make *V. cubensis* easily recognizable, even when poorly preserved or represented by fragments.

The structure of the exterior of the flange, in side view, confirms the existence of two systems of radial plates as suggested by Palmer (1934, p. 242). The radial plates do not extend vertically across the entire equatorial layer, as assumed by Vaughan and Cole (1943, p. 99). On the contrary, those at the top of the equatorial layer are completely separated by a narrow median gap from those at the bottom. The gap exists in specimens of all growth stages (Vaughan and Cole, 1943, p. 98). As a rule, the two systems of radial plates alternate (text-figs. 3, 4). *Sulcoperculina dickersoni* (Palmer) and *S. cubensis* (Palmer) display in the sulcus basically the same arrangement of radial plates as *Vaughanina* (Palmer, 1934, pl. 14, figs. 6, 7). The radial plates are cut completely by the annular walls. Between the radial plates, large radial stolons

pierce the annular walls above and below the median gap.

In the early part of the neanic stage, the radial plates are low, relatively thick, and straight (text-fig.

3). Later they may become higher, relatively thin, wavy, irregular, and bifurcated toward the median gap (text-fig. 4). This more complex pattern exists only in specimens with a thick peripheral flange. The

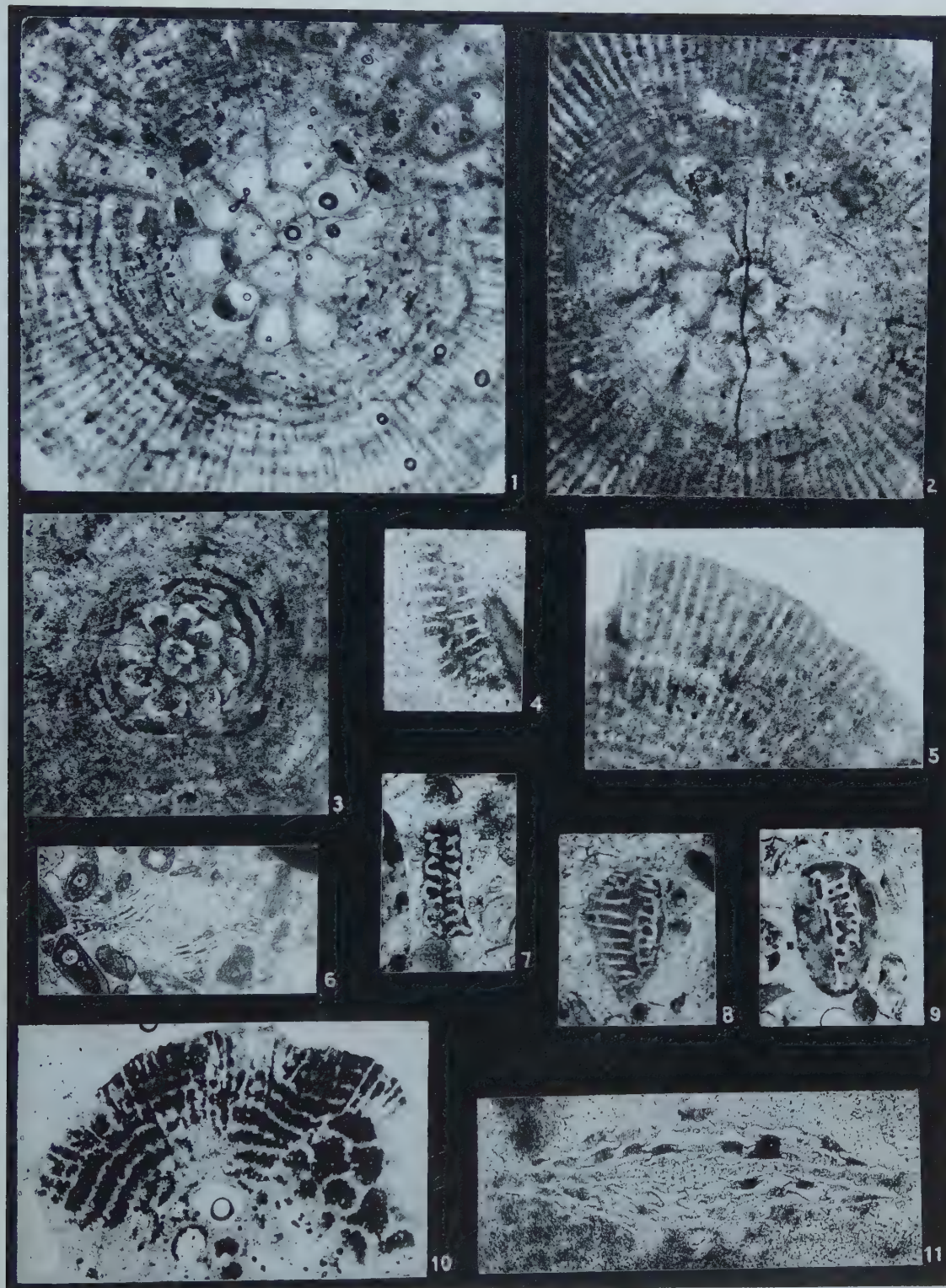


TEXT FIGURE 9 *Vaughanina cubensis* Palmer

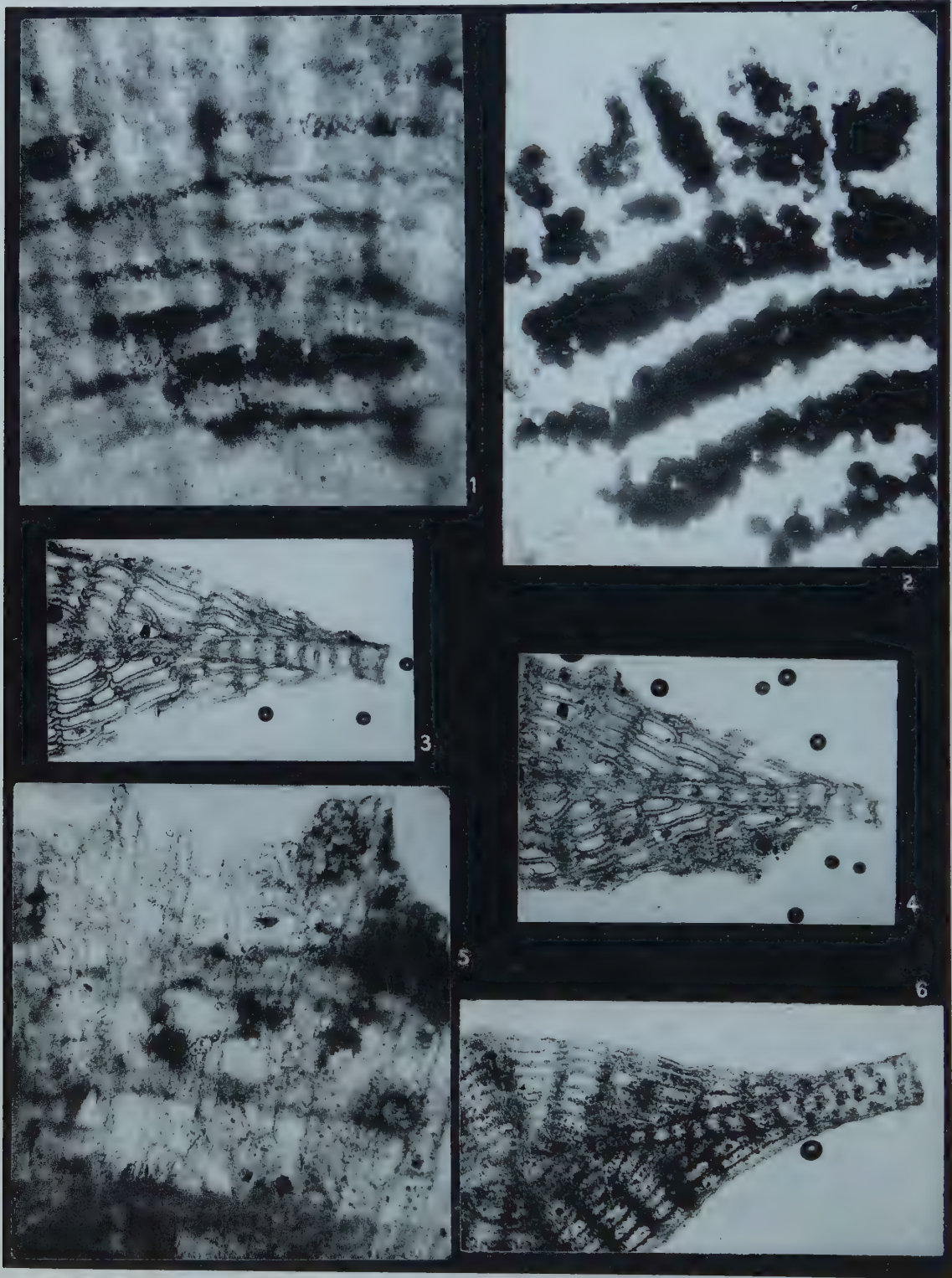
Model of a portion of the equatorial layer near the peripheral flange. The front is directed toward the periphery of the test. It shows the two systems of vertical radial plates, the annular walls, the median gap, the regular meshwork of rectangular "chamberlets," and the walls of opened lateral chambers, stolons, and fine pores.

EXPLANATION OF PLATE 16

Figs.	Figures 1-11 <i>Vaughanina cubensis</i> Palmer	PAGE
	Figs. 1-3, 5, 10 Brown Station 30011.	
	Fig. 11 CUGOC Ser. No. 20753, Las Villas Province.	
	Figs. 4, 6-9 Bronnimann Station 28.	
1.	Juvenarium with peribryonic spiral of 12 chambers. Slightly oblique, disclosing lateral chambers, radial plates and annular walls. 76 ×.	101
2.	Juvenarium with peribryonic spiral of 14 chambers. Tangentially cut; small area of section in the median gap exposing annular chambers (upper left hand side). 81 ×.	100-01
3.	Juvenarium with peribryonic spiral of 13 chambers, surrounded by low elongate chambers. 81 ×.	101
4, 7-9.	Excentric vertical sections, displaying the vertical radial plates, the annular wall and the radial stolons between the radial plates. The radial plates seem to be arranged in pairs. All 78 ×.	100-02
5.	Portion of the equatorial layer in the plane of the radial plates and the radial stolons. 80 ×.	100
6.	Slightly oblique vertical section exposing on each side an "additional horizontal floor" dividing the equatorial layer seemingly in two divisions. 26 ×.	102
10.	Equatorial section of a specimen with undulating equatorial layer, displaying a) annular walls, b) radial and annular walls, c) radial plates, d) lateral chambers, and e) part of the juvenarium. 80 ×.	101
11.	Excentric vertical section showing annular wall with two rows of radial stolons. 31 ×.	102



Bronnimann: Upper Cretaceous *Vaughanina* from Cuba



Bronnimann: Upper Cretaceous *Vaughanina* from Cuba

horizontal distance between radial plates more or less doubles from the center to the periphery. Close to the periphery the plates are nearly parallel. No doubling or trebling of the equatorial layer has been seen. This is in agreement with Palmer (1934, p. 241) who, in comparing *Pseudorbitoides* and *Vaughanina*, noted: "The equatorial layer of *Vaughanina* is single throughout." Vaughan and Cole (1943, p. 99, pl. 18, figs. 8, 9), however, inferred from oblique vertical sections that horizontal plates subdivide the equatorial layer. The detailed external examination of numerous specimens of all growth stages did not reveal such plates. This observation was subsequently confirmed by the analysis of vertical sections of different degrees of obliquity (see p. 102 of this paper).

Except for the gradual ontogenetic change in the radial plates, from a simple to a more complex pattern, the organization of the equatorial layer remains the same from the center to the periphery.

The umbos are well developed in specimens of all sizes. Small specimens of about 0.5 mm in diameter possess no or only a few small pillars in the center of the umbo. On the other hand, specimens with a diameter of about 2.0 mm or more exhibit numerous pillars regularly distributed over the whole umbo. Pillars of larger specimens are in the center 80-100 microns thick; those near the peripheral flange are about 20

microns thick. The lateral chambers are large, irregularly arranged over the central part of the umbo, and elongate near its margin, with the longitudinal axis oriented perpendicular to the periphery of the test (text-fig. 5). The lateral chambers measure about 50-100 microns in diameter. They are connected with the equatorial layer and with other lateral chambers by stolons. As in orbitoidids, the roofs of lateral chambers are finely perforated (Voorwijk, 1937, pl. 3, fig. 4).

Interior.

Equatorial section

1) Juvenarium.

Equatorial sections display a juvenarium comprising a bilocular embryo of variable size and a single nepionic spiral of variable length. This differentiation is based on the central position of the first stolon and on the orbitoidal arrangement of the first chambers, which is especially distinct in juvenaria with a short nepionic spiral (text-figs. 7, 8). The number of volutions of the nepionic spiral ranges from one to two. Juvenaria with short periembryonic spirals and large embryonic chambers resemble closely those of primitive orbitoidal Foraminifera, e. g. *Polylepidina*, *Orbitocyclina*, and others (text-fig. 7). Those with long periembryonic spiral resemble the juvenaria of primitive Miogypsiniids.

The slightly curved wall between protoconch (= chamber I) and deuterconch (= chamber II) is thinner than the outer walls of the embryonic chambers. It is pierced by a large central stolon. The small protoconch is subspherical. The adjoining deuterconch is equal to or slightly larger than the protoconch. The basal stolon of the deuterconch issues into the primary auxiliary chamber. Deuterconch, primary auxiliary chamber and the succeeding chambers of the periembryonic spiral are all connected by basal stolons. Countersepta do not exist. The periembryonic chambers increase gradually in size, but the final chamber or chambers of the spiral may be slightly smaller than the preceding ones. In well-centered equatorial sections, the outer walls of the embryo and of the periembryonic chambers are practically of the same thickness. Toward the lateral layers, the walls of the chambers of the juvenarium are perforated by fine pores. Stoloniferous passages have not been observed.

The following table lists dimensions of the elements of the juvenarium measured in equatorial sections.



TEXT FIGURE 10

Vaughanina barkeri Bronnimann n. sp.

Chalchijapa River, Isthmus of Tehuantepec, State of Veracruz, Mexico (coll. H. E. Thalmann). Appr. 100 X. Juvenarium showing a system of true canals in the walls of the periembryonic chambers (after a drawing by R. Wright Barker).

EXPLANATION OF PLATE 17

Figures 1-6 <i>Vaughanina cubensis</i> Palmer		PAGE
Figs.	Figs. 1-5 Brown Station 30011. Fig. 6 Palmer Station 1214.	
1.	Same specimen as fig. 2, pl. 16, showing arrangement of low elongate chambers near juvenarium. Appr. 414 X.	101
2.	Same specimen as fig. 10, pl. 16, showing annular walls and radial plates. Appr. 400 X.	101
3, 4.	Same specimen. Vertical sections exposing the annular walls, and on both sides of the equatorial layer the radial plates and the median gap. 86 X.	102
5.	Radial plates, with annular walls in a lower plane of the section. Appr. 414 X.	101
6.	Vertical section. Annular walls pierced on both sides of the equatorial layer by radial stolons. 80 X.	101

Where not otherwise mentioned, the section is centered. The juvenaria are arranged according to the number of peribryonic chambers. Dimensions of chambers are inner dimensions.

TABLE I

	Approximate maximum diameter in microns of				
	Chamber I	Chamber II	Primary auxil- iary chamber	Juven- arium	Number of periem- bryonic chambers
POPULATION (1)					
Brown Station					
30011					
No. of specimen					
30011 (1)	26	26	39-52	320	16
30011 (x)	26	26	40	280	14
(embryo slightly tangentially cut)					
30011 (c)	25	40	45	350	13
30011 (8)	32	45	45	270	6
30011 (3)	51	65	77	280	5
30011 (4)	65	77	70	300	5
POPULATION (2)					
Bronnimann Station					
28 (sections 3, 4)					
No. of thin sect.					
28 (3)	24	40	40	260	11
28 (4)	40	40	50-65	280	8
(embryo tangentially cut)					
28 (4)	40	40	50	260	8
(embryo tangentially cut)					
28 (3)	32	35	51	—	*
(embryo strongly tangentially cut)					
28 (3)	77	77	100	260	6
28 (3)	65	77	90	260	5

* Number of chambers not known. Spiral short.

The number of peribryonic chambers, including the primary auxiliary chamber, varies from 5 to 16 in the tabulated specimens. In other specimens a maximum of 18 chambers has been counted; 5 appears to be the minimum number of peribryonic chambers. The size of the juvenarium remains virtually the same irrespective of the number of peribryonic chambers. The reduction of the number of peribryonic chambers is accompanied by an increase in the dimension of the chambers of the juvenarium. Proto- and deuteroconch of juvenaria with 14- and 16-chambered spirals are only about 26 microns in diameter, whereas the embryonic chambers of specimens with 5- and 6-chambered peribryonic spiral have a diameter of about 32 to 77 microns and 45 to 77 microns respectively. Primary auxiliary and following spiral chambers are also much larger in specimens with short spirals than in those with long nepionic spirals. The diameter of the primary auxiliary chamber is about 30 to 52 microns in long spirals, and 70 to 100 microns in short spirals.

The uniserial juvenarium of *V. cubensis* is primitive. One would expect to find in the Cuban assemblages juvenaria with a second peribryonic spiral, issued from the primary auxiliary chamber, or juvenaria with

additional auxiliary chambers and corresponding spirals. But no bi- or multiserial juvenaria have been encountered in the material studied and the only morphologic changes observed in the development of the juvenarium are the reduction of the number of chambers and the corresponding increase in size of the chambers of the peribryonic spiral. These features are numerically determinable and can be used to establish the relative phylogenetic and stratigraphic age of a certain population according to Tan's principle of nepionic acceleration (1935). The simultaneous occurrence in *V. cubensis* of a primitive juvenarium and of highly developed equatorial and lateral layers is remarkable. It is conceivable that the equatorial and lateral layers developed much more rapidly than the juvenarium, and that the final stage of the evolution of these parts of the test was reached before the embryogenesis came to a mature stage. Larger Foraminifera with a similar differential evolution are known in the Miogypsinidae, e. g., *Miogypsina thalmani* Drooger, *Miogypsina basraensis* Bronnimann (Drooger, 1952).

2) Neanic stage.

Depending on the position of the horizontal section in respect to the equatorial layer the neanic stage shows three different patterns. As a rule, the equatorial layer is slightly undulating so that a single horizontal section may show the three patterns combined. This is also true of oblique sections which are often more useful than oriented sections for the analysis of the internal structure of larger Foraminifera.

a) Horizontal section tangential to the equatorial layer.

This type of section is illustrated by figs. 2, 5, pl. 16. Parts of the section are exactly in the plane of the large radial stolons, which pierce the annular walls between the radial plates (fig. 9, pl. 16); the annular walls therefore appear to be absent in these areas of the section. The thick outer walls indicate that the chambers of the juvenarium are tangentially cut (fig. 2, pl. 16). Immediately outside of the juvenarium start the vertical radial plates already mentioned in the description of the exterior. The radial plates are straight and extend without interruption to the periphery of the test. They are not completely smooth but have intermittent minor thickenings, which are possibly parts of the annular walls. High magnification reveals a dark line in the middle of each plate (text fig. 6; fig 4, 7, pl. 16). This feature is known in other orbitoidal Foraminifera and suggests that each plate is composed of two thin lamellae. New plates are occasionally intercalated. The plates are regularly and closely spaced. The distances between the radial plates increase toward the periphery. In quadrants of four different specimens: 32, 33, 35 and 36 radial plates have been counted at the periphery. The radial plates

near the juvenarium are from 5 to 15 microns, and near the periphery from 10 to 30 microns apart. Their thickness ranges from 2 to 10 microns; they are thinner near the center than at the periphery.

Two illustrated thin sections (figs. 1, 2, pl. 16) demonstrate clearly that the radial plates start directly outside the peribryonic chambers and seem to abut against the outer walls of the juvenarium. No "normal equatorial chambers" are intercalated between juvenarium and the roofs of the radial plates. Vaughan and Cole (1943, p. 99) possibly deduced the existence of interposed "equatorial chambers" from their illustrated tangential equatorial section (1943, fig. 2, pl. 18) and from the oblique section (1943, fig. 1, pl. 18) where lateral chambers are sectioned in the vicinity of the juvenarium.

Many radial stolons connect the peribryonic chambers with the equatorial layer. Horizontal sections exhibiting the first radial stolons are rare. Because the equatorial layer is very thin near the juvenarium the true arrangement of the radial stolons in the outer walls of the peribryonic chambers could not be ascertained.

b) *Horizontal section in the plane of the median gap, between the two systems of radial plates.*

This type of section is illustrated by fig. 10, pl. 16 and by fig. 2, pl. 17. Normally only small areas of an equatorial section are in the plane of the median gap.

The radial plates as described on p. 100 are replaced by annular walls. The annular walls do not exhibit passages. The juvenarium is irregularly surrounded by low elongate chambers. Gradually this type of chambers becomes longer, and eventually annular chambers are formed (text fig. 8; fig. 3, pl. 16, fig. 1, pl. 17). This gradual development of the annular chambers is irregular and precludes the existence of an undivided spiral tube as suggested by Palmer (1934, p. 240) and accepted by Voorwijk (1937, p. 197; pl. 3, fig. 1) and by Rutten (1941, p. 37). This early ontogenetic arrangement is similar to that of *Discocyclus* B-form, where the later annular chambers develop gradually around a short embryonic spiral. The annular chambers of *Vaughanina*, including the low elongate chambers around the peribryonic spiral, are true chambers. A subdivision of the annular chambers into chamberlets as in *Discocyclus*, however, does not exist in *Vaughanina*.

The distances between the annular walls are from 10 to 20 microns near the peribryonic spiral and from 20 to 40 microns near the periphery. The thickness of the annular walls ranges from 3 to 10 microns.

c) *Horizontal section between the tangential and the exactly centered position.*

This section is shown in fig. 10, pl. 16 and in fig. 5, pl. 17. It is also illustrated by Voorwijk (1937, pl. 3, fig. 1).

Radial plates and annular walls are combined and form a meshwork of rectangular "chamberlets" previously described from the surface of the flange. The formation of true chamberlets cannot be reconciled with the existence of the two alternating systems of radial plates. No stolons occur between the individual chamberlets.

The three structural patterns as described in the preceding pages and other pertinent features are exposed in horizontal sections as reproduced by fig. 10, pl. 16 and in oblique sections as illustrated by fig. 4, pl. 18. The specimen of fig. 4, pl. 18 is strongly obliquely cut and only close examination discloses an irregular distribution of the radial plates due to the existence of the median gap between the two systems of plates. This is similar to *Sulcorbitoides pardo* Bronnimann, 1954, where, however, the plates are much shorter and coarser. The oblique section also shows the arrangement of the elongate lateral chambers near the equatorial layer, typical for *Vaughanina cubensis*.

Vertical section

The significant features of the vertical section are:

- a) The equatorial layer is clearly limited toward the lateral chambers by roof and floor; it increases rapidly and regularly in height toward the periphery.
- b) The open and thin-walled lateral chambers do not cover the peripheral portion of the equatorial layer; they are arranged in regular tiers of 6 to 9 chambers.
- c) The annular walls are curved toward the center; they are pierced by radial stolons near the roof and the floor of the equatorial layer.
- d) The trochospiral juvenarium is small compared to the neanic portion of the equatorial layer.

Vertical sections can easily be distinguished from *Sulcorbitoides pardo* and forms related to *Pseudorbitoides* H. Douvillé. Palmer (1934, p. 241, fig. 3) has recognized and illustrated these characteristics of *V. cubensis* in an excellent schematic drawing of a vertical section.

The chambers of the juvenarium are slightly compressed (fig. 10, pl. 18). In a few specimens, a slightly trochospiral arrangement of the initial portion and sulcus-like indentations of the walls of the peribryonic chambers adjoining the equatorial layer have been noted (figs. 6, 9, 10, pl. 18). A trochospiral arrangement is suggested by the long peribryonic spiral and by the asymmetric position of the juvenarium of some individuals (Palmer 1934, p. 242). Six to nine layers of lateral chambers occur in the adult, and this number appears to be rather constant.

The radial stolons on both sides of the equatorial layer are visible only in very thin vertical sections toward the peripheral flange, where they become relatively large (fig. 6, pl. 17; fig. 7, pl. 18). Excentric

vertical sections (figs. 7, 11, pl. 16), exhibit frontal views of the annular wall with the two rows of radial stolons. The sections reproduced by fig. 11, pl. 16; figs. 3, 4, pl. 17 are exactly vertical and no additional floors appear toward the periphery. Stoloniferous passages lead from the equatorial layer to the lateral chambers; they are proximal to the annular walls. However, this type of stolon was not observed in equatorial or oblique sections. Fine pores perforate the walls of the equatorial layer toward the lateral layers and also the walls of the lateral chambers. Basal stolons pierce the walls of the lateral chambers. Because the equatorial layer is extremely thin near the center the radial stolons between the chambers of the juvenarium and the equatorial layer are difficult to see (fig. 10, pl. 18). In some specimens two problematic passages, one upon another, have been noted. The equatorial layer seems to be fully developed from the beginning of the neanic stage, and only the size of the structural elements changes during ontogeny.

The radial plates are illustrated in centered vertical sections (figs. 3, 4, pl. 17). They protrude into the equatorial layer from top and bottom and leave an open aisle in the middle part of the equatorial layer. By using high magnifications, the alternating position of the radial plates can be recognized. Vaughan and Cole (1943, p. 99, figs. 8-10, pl. 18) mention the presence of additional "floors" near the periphery. These "floors" apparently divide the equatorial layer into two or three horizontal divisions. The examination of accurately centered vertical sections confirmed the result of the external investigation that no such floors exist. In slightly oblique vertical sections, on the other hand, distinct additional "floors" appear near the periphery. They seemingly exist only toward the periphery where the equatorial layer is about 4 times higher than near the center and the horizontal distances of the radial plates are small in relation to the height of the equatorial layer. These "floors" are successive radial plates cut obliquely.

The number of "floors" in the peripheral portion of the equatorial layer can be used to estimate the degree of obliquity of a vertical section. A slightly oblique vertical section (fig. 6, pl. 16 shows one additional "floor" on both sides. Excentric vertical sections, in part oblique, are illustrated by figs. 4, 7-9, pl. 16 and fig. 8, pl. 18. They exhibit the two alternating systems of radial plates, and between the radial plates, two series of large radial stolons. From these sections it appears that the radial plates are arranged in pairs.

The structural elements of two vertical sections (figs. 3, 4, pl. 17) have been measured, and the dimensions in microns are given in table II.

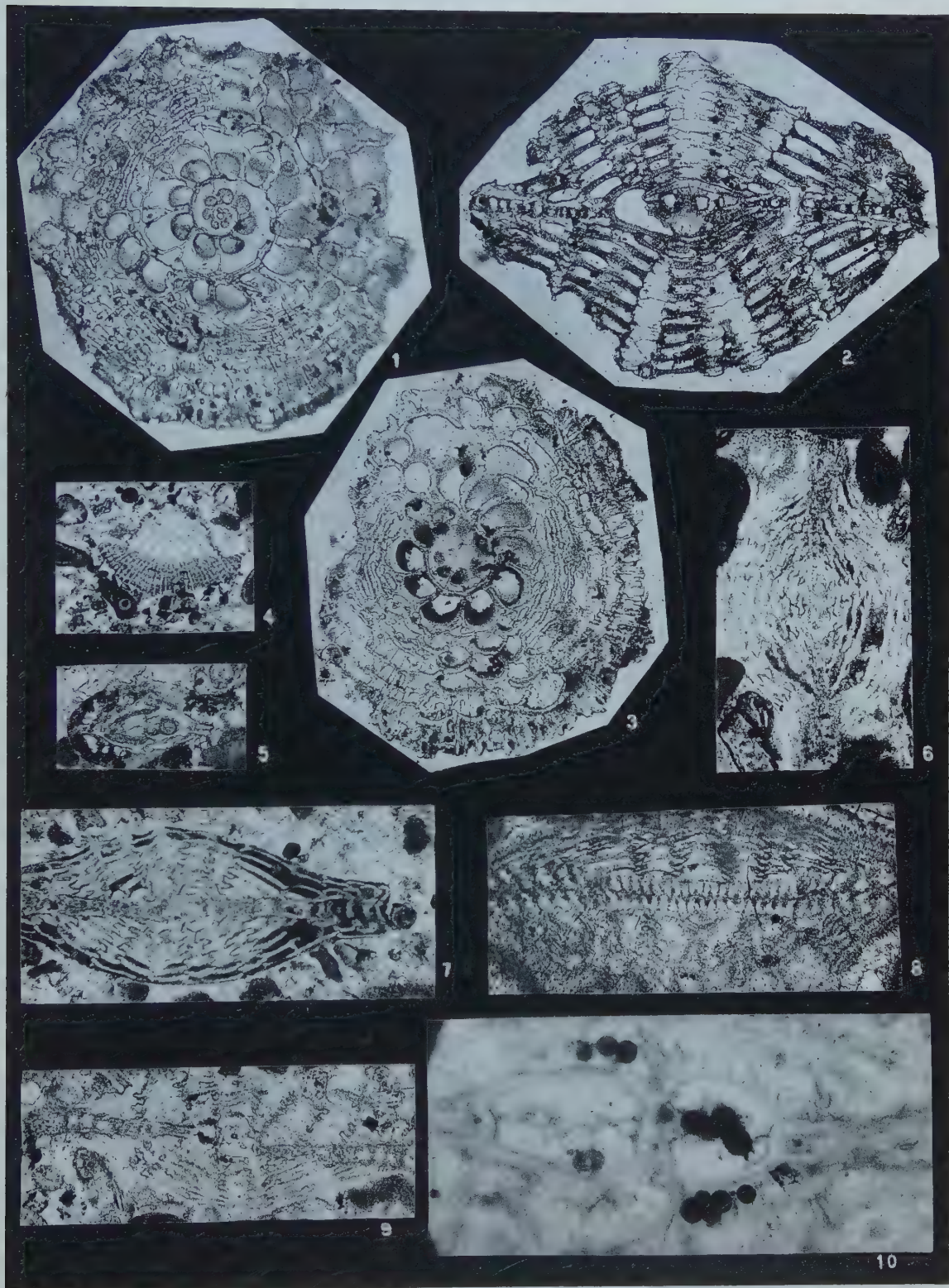
After the completion of the description of *V. cubensis*, the writer received from R. Wright Barker excellent photographs of a vertical thin section and two horizontal thin sections of decalcified preparations of a small species of *Vaughanina*, which had been identified by Barker and Grimsdale (1937, p. 173) as *V. cubensis*. The material was collected by H. E. Thal-

TABLE II (in microns)

Thickness of equatorial layer including walls	No. of Specimen	
	B30011(α)	B30011(β)
near center:	25—40	±25
near periphery:	100—130	±77
Thickness of roof of equatorial layer		
near center:	±5	±7
near periphery:	±11	±8
Diameter of radial stolons:	10—20	10—20
Height of juvenarium including walls:	60—90	±64
Thickness of annular walls		
near center:	±8	±8
near periphery:	±11	±11
Length of lateral chambers without walls:	60—105	38—120
Height of lateral chambers without walls:	±10	9—13
Diameter of pillars:	25—65	35—64

EXPLANATION OF PLATE 18

FIGS.	Figures 1-3 <i>Vaughanina barkeri</i> Bronnimann, n. sp.	PAGE
	Chalchijapa River, Isthmus of Tehuantepec, State of Veracruz, Mexico. All appr. 66 ×.	
1.	Holotype.	103
2.	Vertical section exposing the large sulcoperculinoid initial portion. The v-shaped indentation is clearly visible on the left hand side.	103
3.	Tangential and slightly oblique horizontal section exposing the structural pattern of the equatorial layer of <i>Vaughanina</i>	103
	Figures 4-10 <i>Vaughanina cubensis</i> Palmer	
	Figs. 4-7, 9, 10, Bronnimann Station 28. Fig. 8, Brown Station 30011.	
4.	Oblique section through a strongly umbonate specimen. The arrangement of the radial plates is irregular indicating the median gap and the alternating position. 22 ×.	101
5.	Young individual. 66 ×.	
6-8.	Slightly oblique (fig. 6), and centered (figs. 7, 8) vertical sections. The annular walls and radial stolons are clearly visible in fig. 7. All 66 ×.	101-02
9.	Oblique excentric section close to the juvenarium showing the two systems of vertical plates and occasionally a radial stolon between two plates. The plates occur seemingly in pairs. 66 ×.	101
10.	Chambers of the juvenarium of same specimen as fig. 9, displaying the v-shaped sulci. Appr. 300 ×.	101-02



Bronnimann: Upper Cretaceous *Vaughanina* from Cuba



Kornicker: Plastic Models of Foraminifera

mann at Chalchijapa River, Isthmus of Tehuantepec, State of Veracruz, Mexico. According to Barker, the originals of the photographs are supposed to be deposited in the Collections of Pemex. The three oriented thin sections exhibit the generic features of *Vaughanina*, but they represent a new species of a more primitive character than *V. cubensis*. The description of *V. barkeri* n. sp. is based on the three photographs (figs. 1-3, pl. 18).

***Vaughanina barkeri* Bronnimann, n. sp.**

Plate 18, figures 1-2; text figure 10

Vaughanina cubensis Palmer, BARKER and GRIMSDALE, 1937, Ann. and Mag. Nat. History, Ser. 10, Vol. 19, p. 173.

Holotype.—*Vaughanina barkeri* Bronnimann, fig. 1, pl. 18, Chalchijapa River, Isthmus of Tehuantepec, State of Veracruz, Mexico, Upper Cretaceous. The new species is named for R. Wright Barker for his contribution to the knowledge of the phylogeny of Tertiary orbitoids.

Exterior.—The exterior is not known. From the oriented sections, it can be inferred that the test is strongly umbonate. The slight projection of the equatorial layer on the left hand side of the vertical section indicates a marginal flange (fig. 2, pl. 18). Pillars are regularly distributed. The lateral chambers are large. The outline of the test is finely pectinate.

Interior.

Equatorial section

A good horizontal section of the juvenarium is illustrated by fig. 1 of pl. 18. The bilocular embryo is followed by a spiral of 26, perhaps a few more, periembrionic chambers. The thick outer walls of some chambers indicate that the juvenarium is on one side tangentially cut. Outside of the juvenarium, the equatorial layer displays the regular meshwork of rectangular "chamberlets" typical of *Vaughanina*, formed by the annular walls and by the radial plates. Annular walls alone suggest that the horizontal section passed in places through the median gap. The equatorial layer is in part replaced by lateral chambers.

The other horizontal section, illustrated by fig. 3, pl. 18, is not centered. The long spiraled juvenarium is cut horizontally only in the final whorl, thus suggesting a trochospiral arrangement of the initial portion.

The features of the neanic stage of the equatorial layer are in this specimen better exposed than in the holotype. The three structural patterns of the equatorial layer of *Vaughanina*, viz. the rectangular chamberlets, the annular walls, and the radial plates, are clearly recognizable. The shape of the lateral chambers is similar to that of arcuate to long arcuate, somewhat irregular equatorial chambers. Fissural lumina and canals inside the walls of the periembrionic chambers (text-fig. 10) have been noted in both specimens.

The chambers of the periembrionic spiral are connected by basal stolons. There are no countersepta. Basal stolons exist also in the walls of the lateral chambers. Fine pores perforate the roofs and floors of the equatorial layer, the walls of the chambers of the juvenarium toward the lateral layers, and the walls of the lateral chambers.

Vertical section

The juvenarium (fig. 2, pl. 18) is large in comparison to the neanic stage of the equatorial layer; it is almost as prominent as in *Sulcorbitoides*. It is strongly asymmetric, trochospiral. There is a distinct sulcus and a heavy axial plug as in the small trochospiral *Sulcoperculina* species associated with *Sulcorbitoides pardo* Bronnimann, 1954. Near the juvenarium, the equatorial layer is very thin. It increases regularly in height toward the periphery. The annular walls are slightly concave toward the center. The radial stolons are not recognizable. The roofs and floors of the equatorial layer are thick and limit the equatorial layer toward the lateral chambers.

Seven to nine layers of lateral chambers are arranged in regular tiers.

The dimensions have been measured in the approximately 100 \times enlarged photographs. They are listed in table III.

Diagnostic features.—*Vaughanina barkeri* n. sp. differs from *V. cubensis* by the much larger and distinctly trochospiral juvenarium and by the less rapid increase in height of the equatorial layer. *V. barkeri* n. sp. with its well developed sulcoperculinoid initial stage is phylogenetically more primitive than *V. cubensis*, where also in the long spiraled forms the sulcoperculinoid stage is never prominent.

Occurrence.—*Vaughanina barkeri* n. sp. has been found in Upper Cretaceous beds regarded as equivalent

EXPLANATION OF PLATE 19

(All figures $\times 1$)

FIGS.	PAGE
1. <i>Cornuspira</i> Schultze	109
2. <i>Pyrgo</i> DeFrance	109
3. <i>Gümbelina</i> Egger	109
4. <i>Robulus</i> Montfort	109
5. <i>Dentalina</i> Orbigny	109
6. <i>Peneroplis</i> Montfort	109
7. <i>Quinqueloculina</i> Orbigny	109
8. <i>Haplophragmoides</i> Cushman	109
9. <i>Ammodiscus</i> Reuss	109

TABLE III

	Horizontal sections		Vertical section
	fig. 1, pl. 18	fig. 3, pl. 18	fig. 2, pl. 18
Diameter of test	1.0 mm	0.95 mm	1.15 mm
Thickness of test	—	—	0.9 mm
Diameter of juvenarium	0.52 mm	0.45 mm	0.5 mm
Height of juvenarium	—	—	0.15-0.2 mm
Diameter of initial chamber	+15 microns	—	—
Distances between radial plates	10-20 microns	10-25 microns	—
Distances between annular walls	10-40 microns	10-40 microns	—
Number of radial plates in a quadrant	—	30 to 40	—
Thickness of walls of lateral chambers	±10 microns	±10 microns	10-20 microns
Diameter of lateral chambers	40-110 microns	30-115 microns	30-160 microns
Diameter of pillars near periphery	—	—	30-112 microns

to Upper Méndez, at Chalchijapa River, Isthmus of Tehuantepec, State of Veracruz, Mexico. According to R. Wright Barker (letter of September 28, 1953), the associated fauna contains "*Orbitocyclina*" *minima* (H. Douvillé), *Globotruncana arca* (Cushman), *Globotruncana* cf. *G. canaliculata* (Reuss), *Bolivina incrasata* (Reuss), and other Upper Cretaceous species.

The systematic position of Vaughanina

Vaughanina is a structurally unique genus in the polyphyletic group of Upper Cretaceous orbitoidal Foraminifera. It is related to, but more complex than both *Sulcoperculina* Thalmann, 1938, and *Sulcorbitoides* Bronnimann, 1954.

Relationship with Sulcoperculina

The following features of *Vaughanina* are reminiscent of *Sulcoperculina* or common to both:

1. The uniserial and slightly trochospiral juvenarium.
2. The sulcus-like indentations in the perimebryonic chambers.
3. The two alternating systems of radial plates separated by a median gap.

The structural similarities between *Sulcoperculina* and the early ontogenetic stage of *Vaughanina* suggest that the simpler, rotaloid *Sulcoperculina* represents the ancestral form of the more complex orbitoidal *Vaughanina*.

Relationship with Sulcorbitoides

The morphologic affinities and differences between *Vaughanina* and *Sulcorbitoides* have already been listed in the diagnosis of *Sulcorbitoides* (Bronnimann, 1954, pp. 55, 56), and in the introduction to the present paper.

The two genera are not directly related and lived at different times; they are interpreted as two different lineages derived from *Sulcoperculina*.

Family relationship of Vaughanina

Dorothy K. Palmer (1934, p. 241) placed *Vaughanina* tentatively in the Planorbulinidae, believing the equatorial layer to be formed by an undivided spiral tube. Voorwijk (1937, explanation of plate 3) and

Rutten (1941, p. 37) accepted Palmer's classification. Rutten called attention to resemblances in the general structures of *Vaughanina* and *Pseudorbitoides* H. Douvillé, 1922, and ascribed the simultaneous occurrence of these genera in the same region to a converging trend in their evolution. Vaughan and Cole (1943, pp. 99-100), on the other hand, referred the two genera to the subfamily Pseudorbitoidinae M. G. Rutten 1935 of the family Orbitoididae. This classification was followed in Cole's revision of Vaughan and Cole's article on the Orbitoididae in Cushman's textbook (1948) and adopted in the recent systematic revision of the superfamily Rotaliidea by Bermudez (1952).

Although the orbitoidal test and the structure of the equatorial layer exclude *Vaughanina* from the Planorbulinidae, its true family relationship has not yet been satisfactorily established. It can be clarified only by the morphologic revision of *Pseudorbitoides* H. Douvillé and allied forms, which is made difficult by the fact that the genotype of *Pseudorbitoides* is imperfectly known. The descriptions of *P. trechmanni* by H. Douvillé (1922, 1924), Vaughan (1929) and Vaughan and Cole (1943) are obscure. Douvillé's originals are lost, according to Mme. M. Neumann, Laboratoire de Géologie appliquée, Faculté des Sciences, Université de Paris (letter of April 23, 1953). Topotypes of *P. trechmanni* from the *Barettia* beds at Green Island, Jamaica, have not yet been obtained, and photographs of two poor thin sections of topotypes deposited in the U. S. National Museum are inadequate to revise the diagnostic features. For these reasons, the classification proposed for *Vaughanina* in 1943 by Vaughan and Cole is herein provisionally adopted.

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109. TELEVISION MICROSCOPY FOR MICROPALAEONTOLOGY

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A television camera, using the amazing new pick-up tube, Vidicon, is now available through the Radio Corporation of America, Industrial Division, for use on conventional microscopes. The camera is about the size of a 16 mm movie camera and is connected by cable to a power and monitoring unit weighing approximately 70 pounds. The monitoring unit possesses the control switches, a 10 inch viewing screen, may be plugged into any ordinary 110 volt electric lighting circuit, and connected to one or more conventional home television receivers of any size.

The magnifications obtained depend upon the lenses employed both on the microscope and on the camera and the size of the viewing screen. The Vidicon tube is as sensitive to light conditions as emulsions of ordinary photographic films. The camera can be used successfully with reflected light for ordinary viewing of opaque or semi-opaque microfossils or it can be adapted to viewing thin-sections of fossils by transmitted light. The tube also has a special ability to pick up images transmitted by ultraviolet illumination and show them on the viewing screen with good definition and sharp contrast.

The potentialities of this camera have not been completely explored. It promises to be another new teaching tool because it permits the instructor to demonstrate specimens to the entire class at once. It enables the projection of images of real specimens where previously drawings and photographs were employed. Previous methods of screen projection of opaque specimens by reflected light have not been successful because of the intense light needed to make the image

visible. The Vidicon tube transmits the image using any ordinary microscope lamp as a light source.

The camera may also have promise as a research tool for scanning samples, population counts, and quantitative studies of microfossils and mineral grains. It would relieve the worker of the heavy eye strain that accompanies microscope work.

The camera is as adaptable as any 16 mm movie camera and is finding many new uses, especially in medicine and biology (see references).

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110. PLASTIC MODELS OF FORAMINIFERA

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The standard methods, materials and equipment employed by the mechanical dentist in fabricating dentures were used to create extremely lifelike models of foraminifera. The models of calcareous foraminifera have a smooth white porcellaneous finish, while those of arenaceous foraminifera are buff colored and contain embedded sand grains. The apertures are inlaid with a darker plastic for emphasis. The size of the specimens is from one and one-half to two inches measured along their greatest dimension. Nine forms in all were reproduced. They are shown in the accompanying Plate 19.

Indentations or projections on the surface of the form to be reproduced are reflected in reverse on the internal surface of the mold. If these are angular, part of the mold is destroyed when extracting the plastic model. With more or less symmetrical forms, exemplified by the majority of the foraminifera, surface detail of the mold is destroyed after only two or three castings.

The rapid disintegration of the mold is a disadvantage if quantity production is desired; however, if only one model is required, such as for exhibits, the process may be of value. For this reason the materials and procedure used in making the models are given below:

MATERIALS

1. Dental wax
2. Dental stone (type of plaster)
3. Dental flask (A dental flask consists of a cup-shaped bottom, an open sleeve that fits on top of the cup-shaped bottom, a cover for the sleeve, and a clamp to hold all three parts together.)
4. Liquid and powdered acrylic resins (colorless transparent type)

PROCEDURE

1. Sculpture reproduction in dental wax. The wax is worked easily if warmed over an open flame.
2. Pour "dental stone" into bottom half of dental flask and embed wax reproduction up to its half-way mark. After "dental stone" becomes hard, coat exposed surface with vaseline; attach sleeve to flask. Pour "dental stone" into top half of mold and allow to set.
3. Open flask and remove wax reproduction. Remaining traces of wax are removed by pouring boiling water into mold.
4. Line mold with cellophane or liquid-separating medium marketed for this purpose.
5. Mix liquid and powdered acrylic resins and permit them to react. When a taffy-like consistency is reached, place a wad of plastic into bottom half of mold. White oil pigment is added to the resins when making models of calcareous foraminifera; brown pigment and sand is added in addition to the white pigment when making models of arenaceous foraminifera.
6. Assemble flask and squeeze out excess plastic by compressing in a vise. After removing from vise hold tight with clamp.
7. Heat flask in boiling water for one-half to three-quarters of an hour. Cool in running water, open and remove plastic model.
8. Polish surface of model and inlay aperture.

I wish to thank Thomas Reiersen, mechanical dentist, whose interest and skill made possible the creation of these models.

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111. THE GENUS *HETEROSTEGINA*
IN THE UPPER TERTIARY OF EUROPE

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INTRODUCTION

The development of foraminiferal paleontology during the past three decades was questioned as to the desirability of continuing the usual species description and splitting based on morphologic details without reference to phylogenetic relations. Various publications, especially those of Tan Sin Hok on *Lepidocyclina*, *Miogyxina* and *Cycloclypeus* (see Renz, O. and Küpper, H. 1946), demonstrated that morphogenetic studies have proved to be a useful tool in applied stratigraphy and largely aided in establishing a nomenclatural classification based on phylogenetic relationships. Morphogenetic investigation in contrast to pure species description is based on the study of features which change within taxonomic units during geologic time. Compared with classical stratigraphy which is established on index fossils with a short stratigraphic range morphogenetic analysis makes use of subtle differences and traces them in populations through the stratigraphic column for the purpose of reconstructing evolutionary trends. Thus, not the type of a single stable feature but the height of specialization of a population containing a range of specialized and primitive species becomes characteristic for a stratigraphic unit. Nearly all larger Foraminifera have various and numerous morphological features which may change during a relatively short period of time. This is especially so when both internal and external features are investigated. In dealing with *Heterostegina*s the writers have tried to use both internal and external features in order to determine whether or not their changes are correlative. With regard to stratigraphic questions, the advantage of a recognized evolutionary trend is obvious. The importance of a zonal fossil for a biozone is well established, but the practical application of morphogenetic lineages seems to be barely touched. The abundance and wide regional distribution of larger Foraminifera in certain deposits facilitates the application of morphogenetic studies and their use in stratigraphical correlation.

As the Genus *Heterostegina* is the only genus of larger Foraminifera in the Upper Tertiary of Europe sufficiently distributed to promise results, the writers started with the study of this genus. As space is limited it is impossible to mention and thank all those who kindly provided us with samples and information. We are specially indebted to R. Janoscheck

(Vienna), whose generous support enabled us to make all the illustrations in this paper.

SUMMARY

Tan Sin Hok described the evolution of the genus *Cycloclypeus* and gave an excellent example of a morphogenetic analysis. He established the evolutionary trend of this genus and combined previously described and new species into a phylogenetic system. He also demonstrated the restriction of species to stratigraphic units. This publication is very valuable because a detailed account of all the changes observed and their theoretical interpretation is given. In South East Asia species of *Cycloclypeus* are always associated with other larger Foraminifera. In Europe only *Heterostegina* is found in relative abundance and it is but rarely associated with other larger Foraminifera. Close affinities with *Cycloclypeus* enabled us to apply the same methods as Tan Sin Hok. Papp and Küpper (1952) demonstrated with material from the Vienna Basin that the application of morphogenetic studies in the genus *Heterostegina* was not only possible but promised to render interesting results if sufficient material could be obtained from various localities in Europe.

METHODS

All the morphological features that could be observed internally or externally were taken into consideration. Two different processes, however, were necessary:

- a. Determination of shape and ornamentation of the surface in populations of at least 40-50 specimens.
- b. Study of median sections, at least 15-20 in every population. The combination of both processes results in a definition of the morphogenetic stage of development of each population. In addition suitable material was sectioned for the special purpose to study the anatomy of the genus.

PROBLEMS

- a. Notes on the systematic position of the genus *Heterostegina* and related genera.

A detailed study of the genus requested investigation of its exact systematic position and its differentiation from related genera. It was soon obvious that a redefinition and a subdivision of the genus would be necessary. For this purpose such features were chosen

which allow a characterization as precise as possible. This was especially important because the genus *Heterostegina* is polyphyletic originating from species of *Operculina* several times (see Glaessner 1947).

b. Subdivision of the genus *Heterostegina*.

Applying the method of morphogenetic analysis it is necessary to arrange species into species-groups forming a natural unit of closely related species within one genus. This arrangement is directly related to the often difficult final interpretation of phylogenetic relationship of the species. The method is rather uncomplicated in monophyletic genera but becomes very difficult in polyphyletic genera when several coexisting bioseries occur.

c. Description of species of *Heterostegina* in the Upper Tertiary of Europe.

A detailed study and description of the species occurring in the Upper Tertiary is necessary. Only a few species were named and differentiated in literature. Since this study revealed ample evidence of morphological differences this fact had to be accounted for in nomenclature.

d. Stratigraphic interpretation.

The purpose of this study is to use the established bioseries for stratigraphical questions. A solution towards two different problems was sought:

1. Evolution of the genus *Heterostegina* in the Vienna Basin.

An analysis based on as many populations as possible from different zones in the Tortonian of the Vienna Basin resulted in a neat subdivision and a better understanding of previously introduced zones.

2. Comparison of the species from the Vienna Basin with those from the Upper Tertiary of France.

As larger Foraminifera usually have a wide distribution it was expected that a morphogenetic analysis of *Heterostegina* from both areas would make a detailed correlation possible. Finally, the most important problem of the Helvetian-Tortonian boundary was investigated.

GENERAL REMARKS ON THE SYSTEMATIC POSITION OF THE GENUS *HETEROSTEGINA*

The genus *Heterostegina* Orbigny is usually placed in the family *Nummulitidae* (family *Camerinidae* in Cushman 1950). This family is divided into the following subfamilies by Glaessner (1947) and Cushman (1950):

1. Subfamily *Nummulitinae*
2. Subfamily *Heterostegininae*

The genera *Archaeodiscus* Brady 1873 and *Nummulostegina* Schubert 1907 do not belong to the family of Meso- and Cenozoic *Nummulitidae*. The subfamily *Heterostegininae* primarily included the following genera:

Heterostegina Orbigny 1826
Cyclocypeus Carpenter 1856
Spiroclypeus Douvillé 1905

However, we are of the opinion that, if a subdivision into subfamilies is unavoidable, the following genera should also be included in the *Heterostegininae*:

Operculina Orbigny 1826
Operculinoides Hanzawa 1935
Operculinella Yabe 1918

The systematic position of the two latter genera is not yet definitely settled. It is possible that they will be given subgeneric rank. The genus *Operculina* Orbigny is so closely related to *Heterostegina* that a differentiation even at specific level is difficult in some populations. This genus has to be regarded as the ancestor of all species of *Heterostegina*. The anatomy is identical except for secondary septa lacking in *Operculina*. Since even in this respect continuous gradations between the two genera have been observed, an artificial differentiation has to be introduced.

According to these conditions the following diagnoses are proposed:

I. *Nummulitinae*: embryonic chambers in the megaspheric generation large, in contrast to the microspheric generation.

II. *Heterostegininae*: Embryonic chambers of the two generations difficult to distinguish because of the small difference in size.

To distinguish between *Heterostegina* and *Operculina* and the more specialized genera *Cyclocypeus* and *Spiroclypeus* the following diagnoses are proposed:

1. *Operculina* Orbigny 1826: Test spiral, subdivided into chambers by primary septa without any secondary septa.

2. *Heterostegina* Orbigny 1826: Test spiral, subdivided into chambers by primary and secondary septa.

Both genera, *Heterostegina* and *Operculina*, include involute and evolute species, which allows a further subdivision of the genera. Lateral chambers or annular chambers are advanced specialisations of *Heterostegina*.

3. *Spiroclypeus* H. Douvillé 1905: Test of the involute *Heterostegina*-type with additional lateral chambers.

4. *Cyclocypeus* Carpenter 1856: Test with annular chambers succeeding reduced *Heterostegina*-stage. (synonym: *Heteroclypeus* Schubert 1906).

Cyclocypeus has been studied in great detail by Tan Sin Hok who demonstrated that primitive species have a relatively large *Heterostegina*-stage whereas younger and more specialized ones have only rudiments of this stage with a predominant number of annular chambers.

It has to be emphasized that the four genera quoted are closely related to each other. Their taxonomic differentiation does not imply different descentance but is based on morphologic characters only. Since morphologic features reflect different stages of specialization

they are regarded to be of taxonomic value of generic rank. Primary septa are smooth in *Operculina*, but as soon as the first, often even short secondary septa are observed we are dealing with a *Heterostegina*, although in the same population many specimens may be found that have to be referred to *Operculina*. The test of *Heterostegina* may have an umbilical thickening, but as soon as the first lateral chambers are observed it is a *Spiroclypeus*. The test of *Heterostegina* is entirely spiral. The spiral itself may be opening more or less rapidly, or the test may become involute; but as soon as the first row of annular chambers is present it is a *Cycloclypeus*. This, apparently, is the only consequent possibility to differentiate the genera.

SUBDIVISION OF THE GENUS *HETEROSTEGINA*

It is possible to distinguish within the genus *Heterostegina* species with evolute and involute tests. The evolute species are better known and represented by many species with incompletely developed secondary septa, although some species may have completely developed secondary septa. The involute species are poorly known in their evolution and, apparently, are mostly represented by species with completely developed secondary septa. It is unknown whether the involute species of *Heterostegina* originated from an involute *Operculina* or from a *Heterostegina* becoming involute.

The genus *Heterostegina* is polyphyletic. Species of *Operculina* gave rise to *Heterostegina* at several times during the Tertiary by developing species with secondary septa. The stage of *Heterostegina* with completely developed secondary septa and with an involute test, therefore, may be found at different times without intermediate species. At present it is not yet possible to give a complete account of all the different bioseries involved. For this reason we propose to introduce a preliminary subdivision of the genus into two major morphological groups.

Heterostegina costata Orbigny is regarded as a typical representative of evolute planispiral species, and is a common species occurring frequently in the Upper Tertiary of Europe. This type of *Heterostegina* is called "planiform." The genotype of *Heterostegina* is *Heterostegina depressa* Orbigny. Although this recent species has completely developed secondary septa, and its type figured by d'Orbigny is distinctly evolute, it is pictured in literature always as involute, apparently on account of incorrect determination by Brady (see Cushman 1950).

In contrast to planiform the term "involutiform" is used to designate those species characterized by an involute test. Typical for this type is *Heterostegina involutiformis* n. sp.

This typification is used here as a substitute for subgenera. Subgenera are difficult to define in poly-

phyletic genera if the phylogeny of the whole genus is not completely known. They should include species of one bioseries only and preferably not stages of evolution in different bioseries with the same morphologic character.

In literature the following fossil species are frequently cited belonging to the involutiform *Heterosteginas*:

- H. anghiarensis* Silvestri Oligocene, Italy
- H. assilinooides* Blankenhorn Upper Oligocene, Syria
- H. borneensis* Van der Vlerk Tertiary, Borneo
- H. carpatica* Uhlig Eocene, Carpathians
- H. cubana* Cizancourt Upper Eocene, Cuba
- H. glabra* Osimo Upper Eocene, Indonesia
- H. helvetica* Kaufmann Upper Eocene, Switzerland
- H. nuda* Keyzer Upper Eocene, Cuba
- H. texana* Gravel and Hanna Upper Oligocene, Texas
- H. reticulata* Rüttimeyer Eocene, Switzerland
- H. cf. depressa* in Tan Sin Hok Lower Oligocene, Java
- H. depressa involuta* Silvestri Lower Miocene, Somaliland

According to the type figure of Orbigny *Heterostegina depressa* should be listed with the planiform *Heterosteginas*. The majority of recent *Heterosteginas* belong to the involutiform *Heterosteginas*:

- H. antillarum* Orbigny Antilles, Cuba
- H. curva* Moebius Mauritius
- H. niasi* Verbeek Nias, Sumatra
- H. suborbicularis* Orbigny Sandwich Islands, Mariana Islands

To the planiform species of *Heterostegina* belong the following:

- H. antillea* Cushman Oligocene, Long Island
- H. bantamensis* Tan Sin Hok Lower Oligocene, Java
- H. complanata* Meneghini Neogene, Italy
- H. israelskyi* Gravel and Hanna Upper Oligocene, Texas
- H. papyracea* Seguenza Helvetian, Italy
- H. papyracea gigantea* Seguenza Aquitanian, Italy
- H. praecursor* Tan Sin Hok Lower Oligocene, Java
- H. ocalana* Cushman Upper Eocene, Florida
- H. ruida* Schwager Eocene, Lybia

According to this compilation both involutiform and planiform *Heterosteginas* occur in the Eocene. In the Upper Tertiary of Europe planiform *Heterosteginas* are found at various localities, but so far only one involutiform species, namely *H. involutiformis* n. sp., has been found at a single locality: Saucats, France. In recent deposits of tropical regions involutiform *Heterosteginas* dominate.

DESCRIPTION OF THE *HETEROSTEGINAS* FROM THE UPPER TERTIARY OF EUROPE

a. Definition of morphological terms.

To secure a better understanding a short description

of the technical terms used in this paper is given:

1. Test.

Test involutiform: the central part or umbonal region, shows a pronounced thickening of the test caused by the chambers reaching over the previously formed ones up to the centre of the test. In some Eocene species the chambers are distinctly overlapping but no lateral chambers have been formed.

Test planiform: test coiled in one plane, no distinct umbonal thickenings, and no extension of chambers over previously formed ones. The centre itself is marked by a small distinct knob only in a few species. The primary septa are often seen from the outside of the test because of the lack of overlap.

2. Ornamentation.

Smooth specimens: except for the usual uneven surface found in all genera of the subfamily no sculptural elements are present. Occasionally specimens derived from coarse sands show unevenness of accidental origin caused by solution or weathering.

Specimens with centrally located ornamentation: a distinct granulation may be observed in the center of the test, caused by very flat pillars.

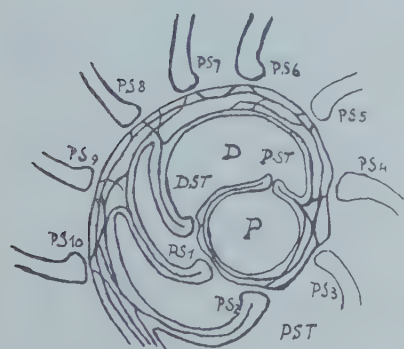
Specimens entirely ornamented: granulation caused by flat pillars spread over the whole test. It is usually

concentrated on the primary septa. The pillars are best developed on the junction of primary and secondary septa. The primary septa are sometimes marked as a continuous rib on the outside of the test. There may be a fine granulation on the test between the septa (see plate 21, fig. 3).

3. Median sections.

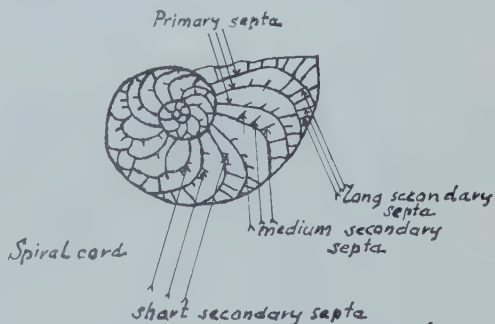
A horizontal section through the centre of the test reveals the first initial chamber or protoconch. A kidney-shaped chamber which partially embraces the protoconch is called the second initial chamber or deuteroconch. Following immediately the two initial chambers is the spiral chord. Its outline marks the opening of the spiral. Throughout the whole test primary septa grow in the direction of the centre, thus having a proximal direction of growth. When describing these morphological features the first fifteen primary septa are called the first primary septa, the next fifteen the middle primary septa and the remainder the younger primary septa.

Short secondary septa are only found in the most primitive species very closely related to *Operculina*. They are very short elongations perpendicular to the internal wall of the primary septa. They are caused by folding of the internal layer of primary septa. The

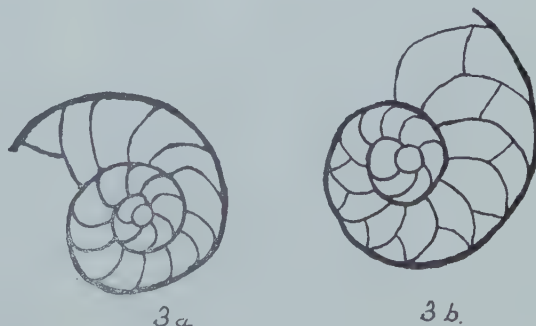


P = Protoconch
D = Deuteroconch
PS1-10 = Primary septa
PST = Protoconch
DST = Deuteroconch
PS7 = Primary septon

2.



1



3a

3b

TEXT PLATE 1

- Fig. 1 Schematic drawing of *Heterostegina costata* Orbnig in median section to explain morphological features.
- Fig. 2 Embryonic apparatus of *Heterostegina costata* Orbnig with canalsystem drawn and combined after section No. P. 131, P. 134, P. 135, all from Koste, Roumania.
- Fig. 3a, b Median sections of *Heterostegina granulatatesta granulatatesta* Papp and Küpper, Rauchstallbrunngraben near Baden. a: Microspheric, b: Megalospheric specimen.

first short secondary septa appear as minute folds of this layer and can be defined and recognized as septa only because of the varying stage of development in one and the same section. Medium-sized secondary septa extend to approximately half the distance between two primary septa, but they do not connect with the opposite primary septum. Long secondary septa contact between primary septa. The stage of development of the secondary septa is an indication of the specialization. Populations with predominantly short secondary septa are more primitive, older, and closer to *Operculina* than populations with medium and long secondary septa.

b. The anatomy of *Heterostegina*.

Excellent preservation in some populations from Kostež and Baden offered the opportunity to study some structural details. Good results were obtained by staining the thinsections with safranin red preceded by a short covering with chromic acid.

1. The stolons (see text plate 1, fig. 2). The protoconch is connected with the deutoconch by a stolon in an external position, the protostolon. The deutoconch stolon connecting the deutoconch with the first primary chamber has a similar position but is situated directly on the protoconch. Those species characterized by long secondary septa, connecting primary septa with each other, have secondary stolons in the primary septa.

2. The Canalsystem (see text plate 1, fig. 2, pl. 20, figs. 1, 2, 7). The canalsystem especially in the spiral cord is very complicated but similar to that of *Operculina*. In the primary septa there are two superimposed canals connected with each other (see pl. 20, fig. 2). In the spiral cord itself a complicated bundle of canals is present. There are also canals in the secondary septa but nothing definite can be said about their structure and outline.

The canalsystem begins in the protoconchal wall. *Heterostegina costata costata* Orbigny from Kostež is used for the detailed description of the canalsystem in the central part of the test. Beginning near the protostolon a canal turns to the left (see text plate 1, fig. 2), which is connected through the external part of the deutoconchal wall and the primary septum 1 taking an external position in the spiral chord. From the protostolon to the right another canal is found which soon divides into several branches, leading to primary septa and building a connection with the outer wall of the protoconch (in this example the primary septa 2, 3, 4). Another branch is in an external position leading into the deutoconch. The deutoconch, therefore, has two canals. These canals build connections with the primary septa 5, 6, 7, and are connected with each other in the deutoconchal wall.

Near to the primary septum 8 a connection of the innermost canal in the deutoconchal wall with the canals leading into the spiral cord was observed.

The canal originating from the primary septum 1 (PS 1) is divided into several branches; one of them is connected with the primary septa 9 and 10. Additional canals build a three-dimensional system and it is impossible to trace it further with any degree of accuracy. The connection of canals in the marginal cord is not restricted to the primary septa on the internal side of the spiral cord but there is also a connection with the primary septa on the external side, as observed in sections not exactly passing through the stolons but slightly oblique to them.

In the rest of the test the canalsystem is found to be three-dimensional. It is located at the very edge of the spiral cord where the curvature is most pronounced in vertical sections (plate 20, fig. 1). In horizontal sections (plate 20, fig. 7) the numerous canals are very distinct and various types of connection are observable. In vertical sections (plate 20, fig. 1) the bundle of canals is very distinct. The canals of the primary septa connect a younger part of the test with an older one, but even in secondary septa canals are present. Their structural relations could not be unraveled.

c. The Life Cycle.

Most of the specimens examined are megalospheric. Megalo- and microspheric specimens cannot be distinguished from the exterior. The first two chambers show only a slight difference in size in horizontal sections. The spiral is not opening as rapidly in microspheric forms as in megalospheric ones. Some specimens with predominant short secondary septa show additional features which may be used to discriminate the generations. Megalospheric forms start building secondary septa at an earlier stage than microspheric ones. In a general way microspheric specimens are more primitive than the megalospheric ones. Similar relations between the two generations have been observed in other larger Foraminifera.

On text pl. 1, fig. 3a-b the central part of both generations of *Heterostegina granulata testata granulata testata* Papp and Küpper are illustrated. In fig. 3b (megalospheric specimen), the first secondary septa are not found until the 7th primary septum, and the spiral opens rapidly. In fig. 3a (microspheric specimen), the first secondary septum first appears at the 19th primary septum, and the opening of the spiral is much slower. The distinction of generations within the species group of *Heterostegina costata* Orbigny is difficult because the differences are hardly perceptible. A slightly oblique section may give different dimensions of the protoconch. *Operculina complanata* (Defrance) is similar to *Heterostegina granulata testata* in this respect.

The differences of generations are restricted to the earlier part of the test, both in *Heterostegina* and *Operculina*. The middle and younger part of the test are completely identical in both generations, when

seen from the outside and in horizontal sections. It is, therefore, possible to neglect the differences in generations in specific descriptions while in *Nummulites* and related genera these differences are of taxonomic importance.

PLANIFORM SPECIES OF *HETEROSTEGINA*

- a. Remarks on the evolution of some features in the species-group *Heterostegina costata costata* Orbigny.

To characterize a species two morphological features are used:

1. The system of primary and secondary septa in horizontal sections.

2. The ornamentation on the outside of the test.

Both features have an independent evolution. A progressive combination of both features is not necessarily found in every specimen. The direction of evolution can be traced only by studying a sequence of populations, with a minimum of 30-50 specimens, although some populations consisted of several hundred specimens. In total some 3500 specimens from 30 populations were examined for this investigation

1. Horizontal sections with features of primary and secondary septa.

Species of the group of *Heterostegina costata costata* Orbigny in the Upper Tertiary could be traced back to *Operculina complanata* (DeFrance). The most primitive species is *Heterostegina heterostegina* (Silvestri). This species has short secondary septa and is recorded from the Aquitanian to the Helvetian. These septa resemble very thin teeth and are slightly longer near the spiral than in the middle of the primary septum.

The percentage of *Heterostegina heterostegina* (Silvestri) in populations with *Operculina complanata* (DeFrance) increases in younger horizons. In the Upper Burdigalian *Heterostegina heterostegina* was observed as the only representative of this group in our populations. In strata younger than Burdigalian no true *Operculina* was observed in Europe.

Heterostegina heterostegina has, beginning in the Upper Burdigalian, a distinct tendency to increase the length of the secondary septa. This process is imperceptible in populations older than Burdigalian and still is very slow in the Upper Burdigalian and during the whole Helvetian. But primary septa with secondary ones gradually approach the centre of the test, marking a very slow evolutionary process.

In the lowermost Tortonian of the Vienna Basin (Lower Lagenid Zone) a species intermediate between *Heterostegina heterostegina* (Silvestri) and *Heterostegina costata levitesta* n. ssp. is found. The secondary septa are generally higher specialized and longer than in the Helvetian representatives of *Heterostegina heterostegina* (Silvestri). In this species the first long

septa in the distal corner of the primary septa are present. The number of smooth primary septa without any secondary ones is decreased.

In the Upper Lagenid Zone of the Tortonian a further progression of the evolution of the secondary septa is noticed. Medium sized secondary septa are found predominantly, 3-5 long secondary septa are found in most specimens. The number of smooth primary septa is decreased to 1-5 in megalospheric specimens.

The recapitulation of evolution can be traced in one and the same specimen (see text plate 3, fig. 5; text plate 1, fig. 1). The first three primary septa are representing an *Operculina* stage, the next three have one short secondary septum each, the following ones have a variable number of 2-3 long secondary septa and about 3-6 more medium-sized ones, characterizing consecutive stages of *Heterostegina*.

In the youngest strata with *Heterostegina* in the Vienna Basin, the *Bulimina-Bolivina* Zone, the system of secondary septa is further developed. The long secondary septa outnumber the short and medium-sized ones, from which it is concluded that the evolution of secondary septa starts in the distal corner between spiral and primary septum and increases in time to the proximal part of the primary septum. No species exclusively with primary septa has been found so far in the Vienna Basin.

All species and subspecies belonging to the species-group of *Heterostegina costata* Orbigny have rather large embryonic chambers. Megalospheric specimens have a protoconch with a diameter of about 0.2 mm and a deuteroconch of about 0.1 mm.

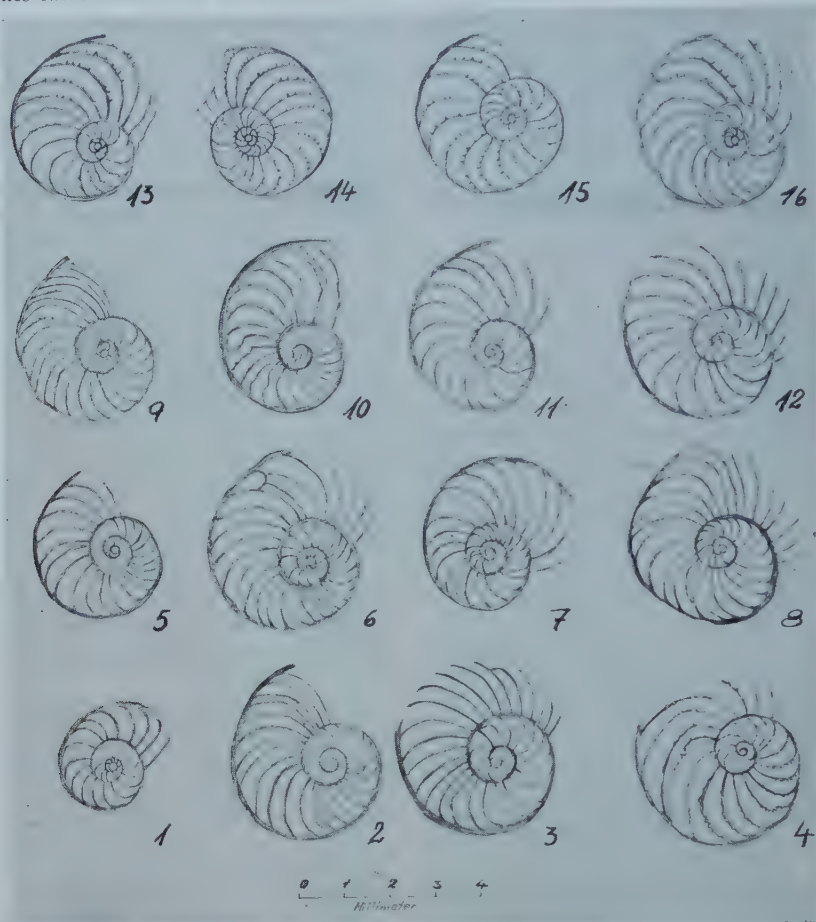
2. Changes in ornamentation.

It appeared to be impossible and very impracticable to distinguish different types within the group of ornamented specimens. No reliable objective discrimination was found to distinguish between species with centrally located ornamentation, ornamentation on the primary septa, raised ribs along the primary septa, or with ornamentation between the primary septa. A summation of all these variable types to a single group of ornamented specimens leads to reliable stratigraphic and phylogenetic results.

Sculptured specimens are first noticed in the Burdigalian. The percentage of sculptured to non-sculptured specimens gradually increases in time. In the Upper Burdigalian (Saucats) it is about 6%, in the lowermost Tortonian of the Vienna Basin (Lower Lagenid Zone) it is about 40%. In the Upper Lagenid Zone an optimum of sculptured specimens (50%) was found in various populations. Higher in the geologic sequence a decrease was noted, and in the *Bulimina-Bolivina* Zone, which yielded the youngest *Heterosteginas* in the Vienna Basin, an average of 99% of smooth specimens were found in large populations.

Although this kind of investigation is very favorable for stratigraphic purposes and phylogenetic interpretation it becomes rather difficult to account taxonomi-

cally for the gradual differences observed. Every population has progressive and primitive specimens, but also includes specimens which are specialized in regard



TEXT PLATE 2

Compilation of morphologic changes in median section from *Heterostegina heterostegina* (Silvestri) back to *Operculina complanata* (Defrance) from the Aquitanian and Burdigalian of France. In younger populations an increase of the percentage of *Heterostegina heterostegina* is found. The secondary septa in specimens from the Upper Burdigalian of Saucats are slightly better developed than in older populations.

Aquitanian:

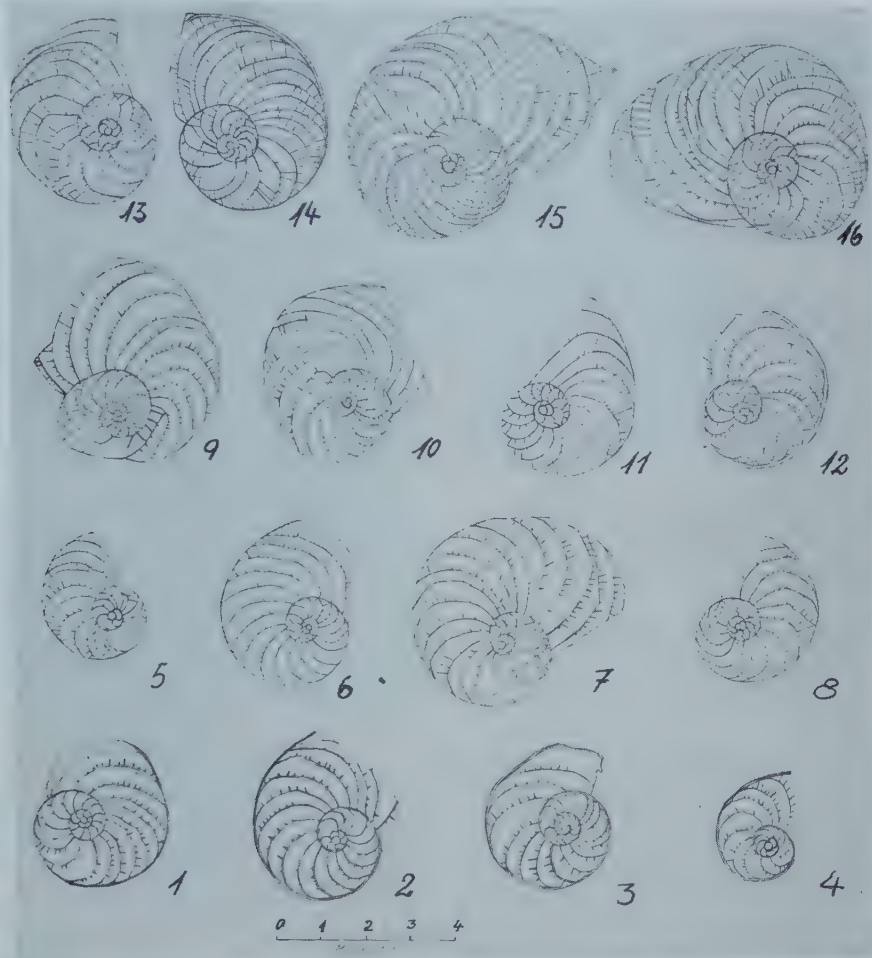
- | | | | |
|---------|--|-----------------|---------|
| Fig. 1 | <i>Operculina complanata complanata</i> (Defrance) | Vieille de Dax | No. 95 |
| Fig. 2 | <i>Operculina complanata complanata</i> (Defrance) | St. Paul de Dax | No. 92a |
| Fig. 3 | <i>Operculina complanata complanata</i> (Defrance) | St. Paul de Dax | No. 92 |
| Fig. 4 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | St. Paul de Dax | No. 91 |
| Fig. 5 | <i>Operculina complanata complanata</i> (Defrance) | Leognan 1 | No. 99 |
| Fig. 6 | <i>Operculina complanata complanata</i> (Defrance) | Leognan 1 | No. 99 |
| Fig. 6 | <i>Operculina complanata complanata</i> (Defrance) | Leognan 1 | No. 96 |
| Fig. 7 | <i>Operculina complanata complanata</i> (Defrance) | Leognan 1 | No. 98 |
| Fig. 8 | <i>Operculina complanata complanata</i> (Defrance) | Leognan 1 | No. 97 |
| Fig. 9 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | Leognan 2 | No. 103 |
| Fig. 10 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | Leognan 2 | No. 100 |
| Fig. 11 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | Leognan 2 | No. 102 |
| Fig. 12 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | Leognan 2 | No. 101 |

Upper Burdigalian:

- | | | | |
|---------|--|---------|----------|
| Fig. 13 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | Saucats | No. 105 |
| Fig. 14 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | Saucats | No. P. 4 |
| Fig. 15 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | Saucats | No. P. 5 |
| Fig. 16 | <i>Heterostegina heterostegina heterostegina</i> (Silvestri) | Saucats | No. 104 |

to the septa and primitive in regard to the sculpture. The predominant character of a population is there-

fore the only criterion to be used for differentiation. In the following diagnoses an attempt is made to dif-



TEXT PLATE 3

Compilation of morphological changes in median section from *Heterostegina heterostegina* to *Heterostegina costata* occurring in the Tortonian of the Vienna Basin. On this plate the stratigraphically earliest specimens of the species-group *Heterostegina costata* with well developed secondary septa are represented.

Lower Lagenid Zone:

- Fig. 1 *Heterostegina heterostegina praecostata* n. subsp. Niederleis No. P. 6
 Fig. 2 *Heterostegina heterostegina praecostata* n. subsp. Niederleis No. P. 7
 Fig. 3 *Heterostegina heterostegina praecostata* n. subsp., Holotype Niederleis No. P. 43
 Fig. 4 *Heterostegina heterostegina praecostata* n. subsp. Kalladorf

Upper Lagenid Zone and Zone with arenaceous Foraminifera:

- Fig. 5 *Heterostegina* sp. intermediate species Kosteĭ No. P. 20
 Fig. 6 *Heterostegina costata levitesta* n. subsp., Holotype, Voeslau No. P. 8
 Fig. 7 *Heterostegina costata levitesta* n. subsp. Baden No. P. 13
 Fig. 8 *Heterostegina costata costata* Orbigny Voeslau No. P. 10
 Fig. 9 *Heterostegina costata costata* Orbigny Rauchstallbrunngraben No. P. 14
 Fig. 10 *Heterostegina costata costata* Orbigny Rauchstallbrunngraben No. P. 15
 Fig. 11 *Heterostegina costata levitesta* n. subsp. Voeslau No. P. 9
 Fig. 12 *Heterostegina costata costata* Orbigny Kienberg No. P. 12

Bulimina-Bolivina Zone:

- Fig. 13 *Heterostegina costata politatesta* n. subsp. Neudorf No. P. 17
 Fig. 14 *Heterostegina costata politatesta* n. subsp. Prinzendorf No. P. 16
 Fig. 15 *Heterostegina costata politatesta* n. subsp., Holotype Brunn No. P. 19
 Fig. 16 *Heterostegina costata politatesta* n. subsp. Brunn No. P. 18

ferentiate the most characteristic populations by several features and separate them by their stratigraphic occurrence.

b. Diagnoses of species.

Operculina complanata complanata (Defrance)

Text plate 2, figures 1-3, 5-8

1822 *Lenticulites complanata* DEFANCE, p. 453.

1826 *Operculina complanata* ORBIGNY, pl. 14, fig. 7-10.

1948 *Operculina complanata* BANNINK, p. 74 (with list of synonymy)

Specimens from the Aquitanian of France are large with diameters up to 10 mm and with rather thick and massive walls, and smooth surfaces. The average diameter of the populations available is about 6 mm. The primary septa are thick and smooth.

Occurrence: St. Paul near Dax (population with very large specimens), Bordeaux, Vieille near Dax, France.

In the Burdigalian the tests are generally smaller and thinner, but in every other respect they are identical with those from the Aquitanian.

Occurrence: Leognan (locality 1), France.

Heterostegina heterostegina heterostegina (Silvestri)

Text plate 2, figures 4, 9-16

1907 *Operculina complanata heterostegina* SILVESTRI, p. 36, pl. 2, fig. 4.

Test with an average diameter of 5 mm, external features identical with *Operculina complanata* (Defrance). The primary septa have on their distal part very short secondary septa.

Occurrence: Aquitanian, St. Paul near Dax, France, very rare. The ratio of *Heterostegina heterostegina* to *Operculina complanata* is 1 : 10. Burdigalian: a sample from Leognan (loc. 1) contained only *Operculina complanata*, another from Leognan (loc. 2) only *Heterostegina heterostegina*. In one sample large specimens were common with an average diameter of 8 mm. In the sample from Saucats "faluns supérieurs" nothing but *Heterostegina heterostegina* was found. In another sample (loc. 2) 6% of ornamented specimens were observed.

Remarks: This species was described by Silvestri from the Middle Helvetian in the Province of Turino, Italy, as a variety of *Operculina complanata* (Defrance). It is unquestionably related to this species but also to the group of *Heterostegina costata* Orbigny from the Tortonian. If this species would be classified as *Operculina* it would be impossible to differentiate consistently *Operculina* and *Heterostegina*. Therefore the subspecies is here given specific rank and placed into the genus *Heterostegina*. In different populations of Aquitanian to Burdigalian age an increase of the percentage of the species of *Heterostegina heterostegina* over *Operculina complanata* has been observed.

According to our samples the following data were compiled:

	<i>O. complanata</i>	<i>H. heterostegina</i>
Upper Burdigalian	0%	100%
Middle Burdigalian	50%	50%
Aquitania	90%	10%

Although no topotypes were available for comparison, an identification seems to be well justified after Silvestri's excellent illustrations and description. Our material from Saucats is almost identical with Silvestri's specimen. His Middle Helvetian population fills the gap in material between Upper Burdigalian and Lower Tortonian.

Heterostegina heterostegina praecostata, n. subsp.

Text plate 3, figures 1-4; plate 21, figures 7, 8

Holotype: Text plate 3, figure 3, No. 43.

Derivatio nominis: ancestral subspecies related to *H. costata*, prae = before.

Locus typicus: Niederleis, Lower Austria, Austria.

Stratum typicum: Tortonian, Lower Lagenid Zone.

This form is closely related to *Heterostegina heterostegina heterostegina* (Silvestri), usually smooth, with or without heavy ornamentation. Secondary septa are medium-sized. Long secondary septa occur very occasionally and then only in the very distal part of a primary septum near the spiral.

Occurrence: Tortonian, Lower Lagenid Zone, Niederleis and Kalladorf, Lower Austria.

Heterostegina costata levitesta n. subsp.

Text plate 3, figures 6, 7, 11; plate 23, figure 2

Holotype: text plate 3, figure 6, No. P. 8.

Derivatio nominis: levis = smooth, testa = test: on account of the smooth test.

Locus typicus: Voelau, Lower Austria (Breyer's brickyard).

Stratum typicum: Tortonian, Upper Lagenid Zone.

Test without sculpture similar to *Heterostegina heterostegina praecostata* n. subsp., but with more specialized secondary septa. In the younger part of the test near the spiral cord there are numerous medium-sized secondary septa and usually 2-3 long ones. Only very few specimens with 4-5 long secondary septa have been observed.

Occurrence: Tortonian, Lower Lagenid Zone, Kalladorf; Upper Lagenid Zone: Voelau, Baden, Raustallbrunngraben, Steinabrunn, Austria; Zone with arenaceous Foraminifera: Grinzing and Kalksburg, Austria, Raussnitz, Czechoslovakia.

Heterostegina costata costata Orbigny

Text plate 3, figures 8-10; plate 20, figures 1-7;

plate 21, figures 3-6

1846 *Heterostegina costata costata* ORBIGNY p. 212 (pars), Pl. 12, fig. 15 (non fig. 16).

1846 *Heterostegina simplex* ORBIGNY p. 211, pl. 12, fig. 12-14.

1952 *Heterostegina costata* PAPP and KÜPPER p. 7.

The septa are similar to those of *Heterostegina costata levitesta* with numerous medium sized secondary septa in the younger part of the test. Usually 3, and only rarely 4-5, long secondary septa are present near the spiral cord. This species differs from *Heterostegina costata levitesta* in having distinct ornamentation. Three different types of ornamentation were observed:

1. Entirely ornamented with distinct knobs on and in between the primary septa (see pl. 21, figs. 3, 4).

2. Entirely ornamented with knobbed ribs on the primary septa (see pl. 21, fig. 5).

3. Sculpture in the central part of the test only (see pl. 21, fig. 6).

Heterostegina costata costata is differentiated from *Heterostegina heterostegina praecostata* by the higher specialized secondary septa.

Occurrences: Tortonian, Upper Lagenid Zone: Voelau, Baden, Rauchstallbrunngraben, Nussdorf-Schreiberbach, Steinabrunn; Tortonian, Zone with arenaceous Foraminifera: Kienberg, Raussnitz.

Remarks: d'Orbigny, 1846, described two species: *Heterostegina costata* and *Heterostegina simplex*. The latter is a juvenile *Heterostegina costata* and, therefore, a synonym. This is evidenced by the small size and the fact that only one secondary septum is observable on the last primary septum. The same structural details are found in the central part of adult specimens of *Heterostegina costata*. D'Orbigny pictured two different specimens on his pl. 12, figs. 15, 16, as *Heterostegina costata*. Fig. 15 is a specimen with an entirely ornamented test, without secondary septa visible on the outside of the test. This specimen is here designated as the holotype of *Heterostegina costata costata* Orbigny. Fig. 16, however, illustrates a different species characterized by highly specialized secondary septa visible from the outside of the test. Because this species does not belong to the same bioseries as *Heterostegina costata* it has been separated from *Heterostegina costata* and been named *Heterostegina granulata* Papp and Küpper 1952. It can be easily distinguished from *Heterostegina costata* by the higher specialisation of the secondary septa, the smaller size of the protoconch and the dense granulation of the test. Even in mixed populations where both species occur together they can be easily separated. The description of d'Orbigny on p. 212 apparently deals with both species. Since *Heterostegina costata* Orbigny (*sensu* Papp and Küpper) figured in d'Orbigny, 1846, on pl. 12, fig. 15, is more common in the Vienna Basin it has been chosen as the type for the commonly used name *Heterostegina costata* Orbigny. The type locality for this species is given by d'Orbigny on p. 212 as "Nussdorf." This locality is no more accessible but according to the fauna described it certainly belongs to the Upper La-

genid Zone. The other localities near Nussdorf belong to the *Bulimina-Bolivina* Zone of the Tortonian.

Heterostegina costata politatista, n. subsp.

Text plate 3, figures 13-16; plate 21, figure 2

Holotypes: text plate 3, figure 15, No. P. 19.

Derivatio nominis: politus = polished, testa = test. On account of the smooth test.

Locus typicus: Brunn near the Schneebergbahn, Lower Austria, Austria.

Stratum typicum: Tortonian, *Bulimina-Bolivina* Zone.

Test smooth, usually larger and thicker than in *Heterostegina costata levitesta*. The septa are higher developed in the last whorl only, 2-3 medium-sized secondary septa and more than 5 long ones are present.

Occurrences: Tortonian, *Bulimina-Bolivina* Zone: Brunn near the Schneebergbahn, Prinzendorf at the Steinberg, Neudorf on the March (Sandberg).

Heterostegina costata carinata n. subsp.

Holotype: plate 21, figure 1.

Derivatio nominis: carina = the characteristic keel on the spiral.

Locus typicus: Neudorf on the March (Sandberg) C.S.R.

Stratum typicum: Tortonian: *Bulimina-Bolivina* Zone.

Test with rapidly opening spire, smooth surface; septal arrangement similar to that of *Heterostegina costata politatista* but differentiated on account of the rapidly opening spire and the presence of a carina absent in all other subspecies of *Heterostegina costata*.

Occurrence: Tortonian, *Bulimina-Bolivina* Zone, Neudorf on the March, Sandberg, C.S.R.

c. Stratigraphic distribution of the species group *Heterostegina costata* Orbigny in the Vienna Basin.

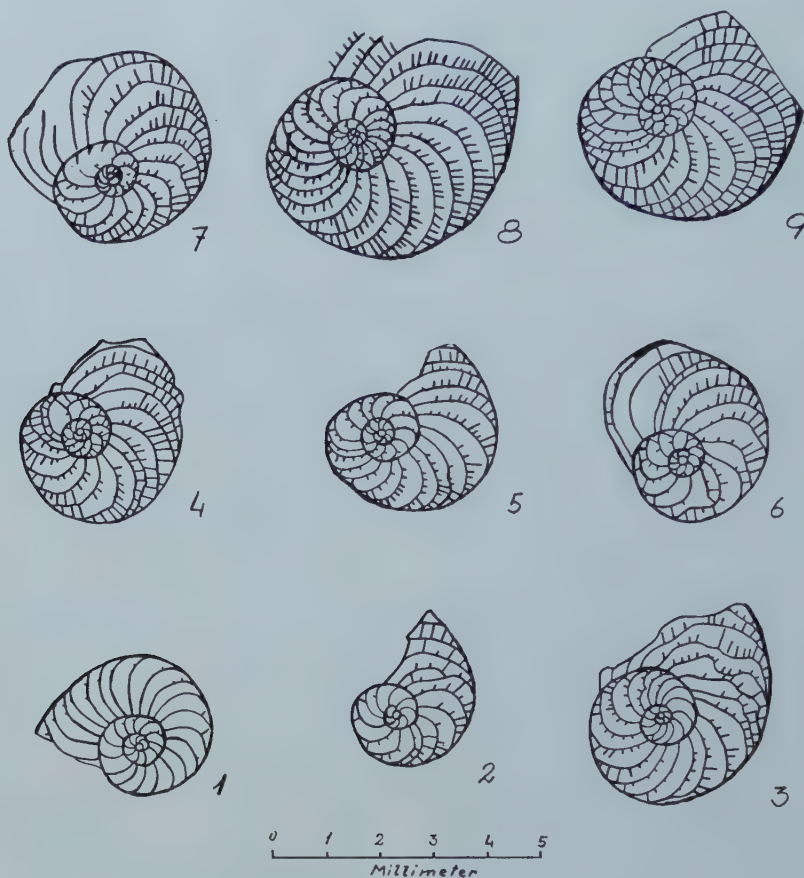
1. Tortonian, Lower Lagenid Zone.

a. Population from Niederleis, Lower Austria, collection Museum Natural History, Vienna. 60% smooth, 40% ornamented. One median section shows one long secondary septum, and a general configuration similar to that of text pl. 3, figs. 1-3. These specimens were separated taxonomically because of their intermediate position between typical Helvetian and Tortonian species and were here named *Heterostegina heterostegina praecostata*. Niederleis is located in a small separate basin in the Klippenzone in a tectonical position similar to that of the Vienna Basin. Grill demonstrated that Tortonian sediments occur in this basin. A careful study of *Uvigerina* confirmed the presence of the Lower Lagenid Zone also corroborated by the study of the *Heterosteginas*.

b. Population Kalladorf, Lower Austria, collected by Weinhandl. 60% smooth, 40% ornamented median

sections as in the afore-mentioned population. For illustrations of median sections see text pl. 3, fig. 4.

In this population *Heterostegina heterostegina praecostata* occurs predominantly although a few speci-



TEXT PLATE 4

Median sections of a population from Raussnitz, Moravia, C.S.R., Zone with arenaceous Foraminifera, Tortonian, No. P. 140-148. All these morphological different specimens occur in one population. Their systematic position is intermediate to the group of *Heterostegina costata costata* and *Heterostegina costata politatesta*.

Fig. 1 Very primitive specimen representing a type resembling *Heterostegina heterostegina* (Silvestri). Very rare in this population.

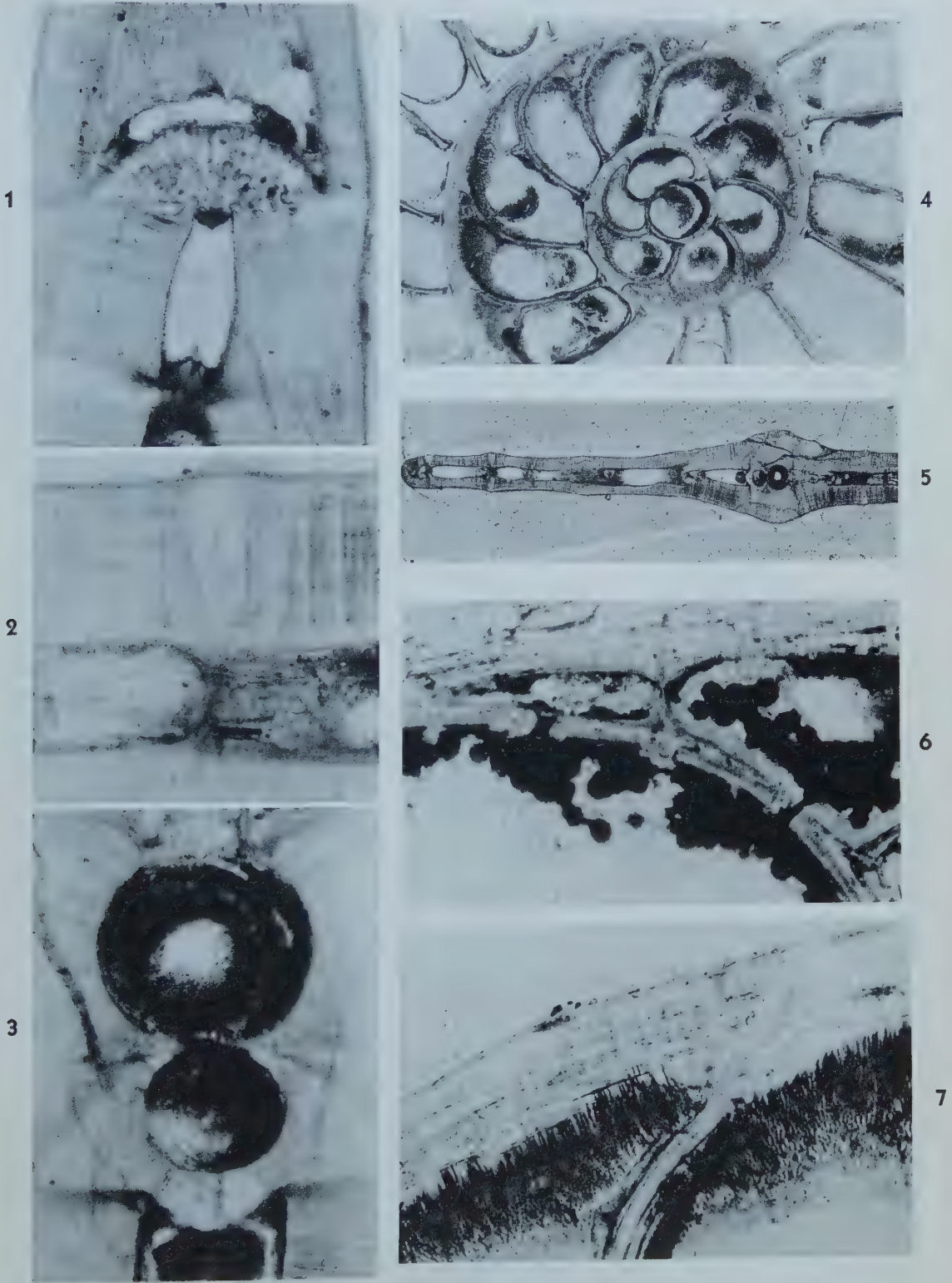
Fig. 2-5 Specimens characterized by numerous medium sized and short secondary septa, resembling *Heterostegina costata levitesta*.

Fig. 6-9 Specimens characterized by several long secondary septa, transitional between *Heterostegina costata politatesta* and *Heterostegina costata levitesta*.

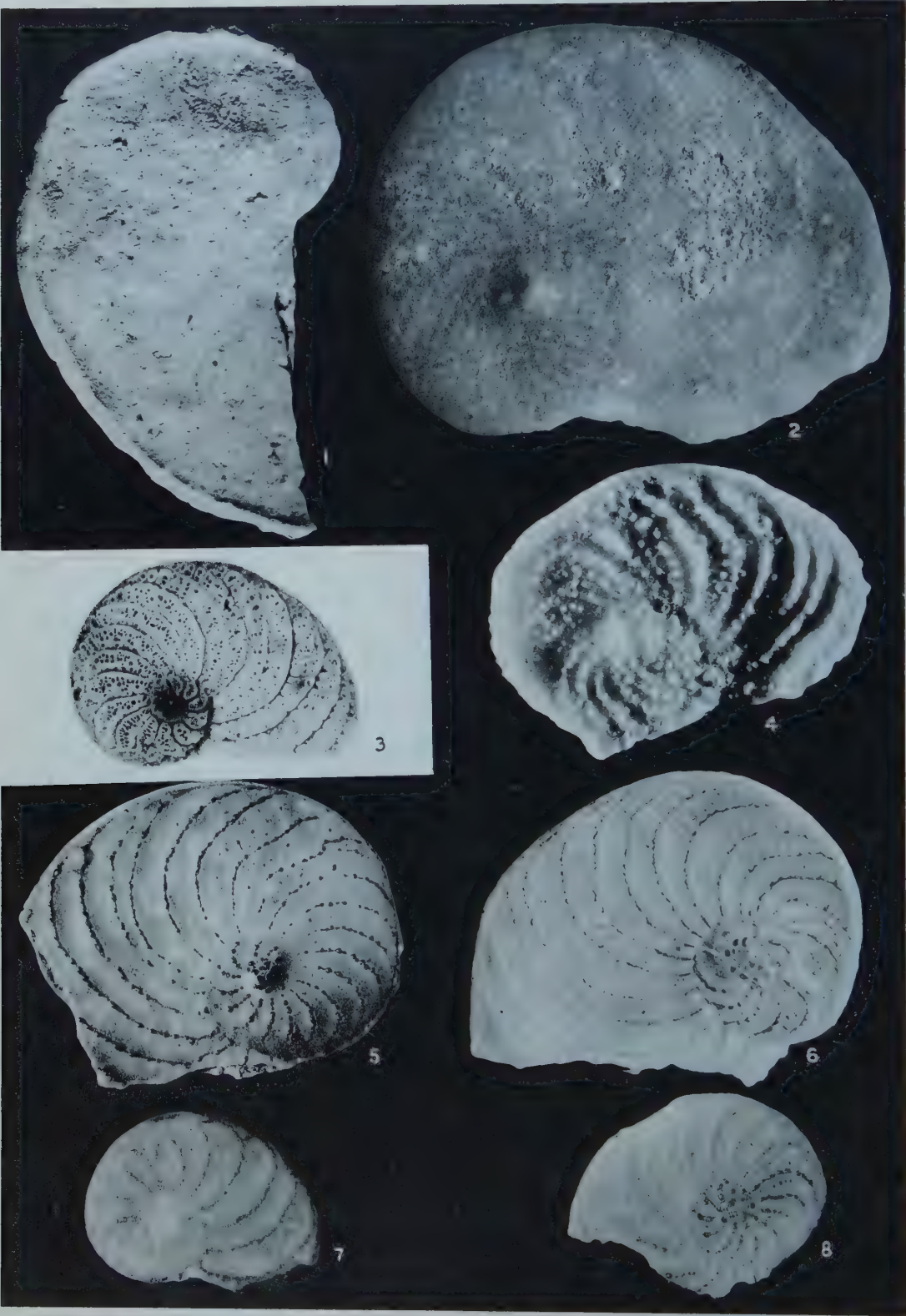
EXPLANATION OF PLATE 20

FIGS.	PAGE
1. <i>Heterostegina costata costata</i> Orbigny, vertical section through spiral cord showing canals. 170 ×, Kostej, Roumania.	112
2. <i>Heterostegina costata costata</i> Orbigny, vertical section through connection of primary and secondary septum with pillar superimposed. 170 ×, Kostej, Roumania.	112
3. <i>Heterostegina costata costata</i> Orbigny, embryonic chambers in vertical section. 170 ×, Kostej, Roumania.	116
4. <i>Heterostegina costata costata</i> Orbigny, horizontal section. 85 ×, Kostej, Roumania.	116
5. <i>Heterostegina costata costata</i> Orbigny, vertical section. 20 ×, Kostej, Roumania.	116
6. <i>Heterostegina costata costata</i> Orbigny, marginal part of the test with stolons in primary septa. Stained with methylene blue. 200 ×, Kostej, Roumania.	116
7. <i>Heterostegina costata costata</i> Orbigny, canalsystem in spiral cord; Note: continuation of canals into primary septa. 200 ×, Kostej, Roumania.	112

All the figured specimens are deposited in the collections of the Paleontological Institute of the University of Vienna.



Papp and Küpper: *Heterostegina* in the European Upper Tertiary



Papp and Küpper: *Heterostegina* in the European Upper Tertiary

mens have to be classified as *Heterostegina costata politatesta*.

2. Tortonian, Upper Lagenid Zone.

a. Two populations from the Rauchstallbrunngraben near Baden. 29 (21)% smooth, 71 (79)% ornamented. They occur in coarse sandy marls with abundant Bryozoa. In thin-sections specimens with many medium-sized secondary septa and a few long ones predominate (see text pl. 3, figs. 9, 10). These populations consist of *Heterostegina costata costata* Orbigny and *Heterostegina costata levitesta*. The type locality of *Heterostegina costata* Orbigny is identical with the Rauchstallbrunngraben in respect to lithology and age,

b. Two populations from Baden near Vienna, lithology: fine sands. 20 (25)% smooth, 80 (75)% ornamented. For a median section representative for this population see text pl. 3, fig. 7.

c. Two populations from Bad Voeslau, fine sands, 15% smooth, 85% ornamented. Sections average the one given on text pl. 3, fig. 6; higher specialized specimens as in text pl. 3, figs. 8, 11 are rare. The smooth specimens are determined in all these populations as *Heterostegina costata levitesta*. The sculptured ones represent the elementary species *Heterostegina costata costata* Orbigny.

d. Population Steinabrunn. This population probably belongs also to this group c): 50% ornamented. Septa similar to the Voeslau population. Since there are only 30 specimens available it is as yet impossible to give a definite determination.

3. Tortonian, Zone with arenaceous Foraminifera.

a. Population Vienna XIX, Grinzing, between Krapfenwaldlgasse and Kasselgasse. 90% smooth, 10% ornamented. In thin-sections a combination of types as pictured on text plate 3, figs. 1-9 is usual. The septal development is intermediate between the populations from the Upper Lagenid Zone and the *Bulimina-Bolivina* Zone. This age-determination could be confirmed with species of *Uvigerina*.

b. Population Kalksburg near Vienna, sand-pit near

the cemetery. 95% smooth, 5% ornamented. In thin-sections types as figured on text pl. 3, fig. 12 are common.

c. Population Raussnitz, C.S.R. collection Museum of Natural History, Vienna. 80% smooth, 20% ornamented (6% centrally ornamented). A series of thin-sections is pictured on text pl. 4. Specimens with medium-sized secondary septa are predominant. Higher specialized or very primitive specimens are very rare. The similarity of this population with that from Grinzing is evident. We do not hesitate, therefore, to date this population as Zone with arenaceous Foraminifera. Raussnitz is located in the extra-alpine Vienna Basin and from this region so far no sediments of this age have been reported. As it was impossible to collect more material and visit the area we have to rely on the information kindly provided by R. Grill. About 1 km South of Raussnitz limestones are known to occur, overlying Lower Tortonian. As our sample probably was derived from the limestones there is no geological evidence against our tentative age determination.

4. Tortonian, *Bulimina-Bolivina* Zone.

a. Population Prinzendorf on the Steinberg, Lower Austria. 99% smooth, 1% ornamented. In median sections only rarely types as figured on text pl. 3, fig. 12 are found. Types as figured on text pl. 3, fig. 14 are abundant. They are characterized by numerous long secondary septa predominating over medium-sized and long ones, in the younger and middle part of the test. This population is of special interest because the strata containing this population were drilled and the cores could be directly correlated with the stratigraphic subdivision given by R. Grill. It belongs to the *Bulimina-Bolivina* Zone.

b. Population Hornstein-Schlossberg, Burgenland, collected by A. Tollman. 98% smooth, 2% ornamented. Sections similar to those from Neudorf on the March. This population either belongs to the uppermost part of the Zone with arenaceous Foraminifera or to the lowermost part of the *Bulimina-Bolivina* Zone.

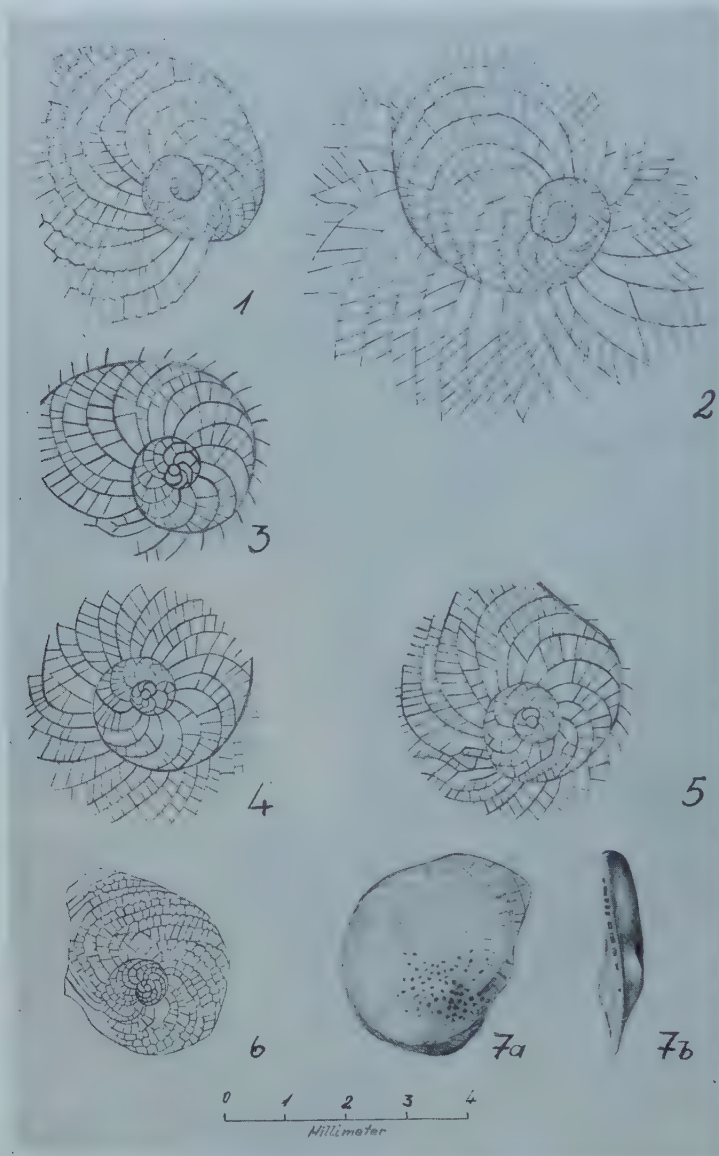
EXPLANATION OF PLATE 21

FIGS.	PAGE
1. <i>Heterostegina costata carinata</i> n. subsp. Holotype, 12 ×, Neudorf a. d. March, Sandberg, C.S.R. No. P. 157	117
2. <i>Heterostegina costata politatesta</i> n. subsp., 12 ×, Brunn a. d. Schneebergbahn, No. P. 156	117
3. <i>Heterostegina costata costata</i> Orbigny, specimen with ornamentation between the septa, transmitted light, 12 ×, Voeslau near Baden, No. P. 152	116
4. <i>Heterostegina costata costata</i> Orbigny, specimen with distinct ornamentation, 12 ×, Rauchstallbrunngraben near Baden, No. P. 151	116
5. <i>Heterostegina costata costata</i> Orbigny, specimen with ornamentation on the primary septa, 12 ×, Kostež, Roumania, No. P. 153	116
6. <i>Heterostegina costata costata</i> Orbigny, specimen with ornamentation in the centre, 12 ×, Kostež, Roumania, No. P. 154	116
7. <i>Heterostegina heterostegina praecostata</i> n. subsp., specimen without ornamentation, 12 ×, Niederleis, No. P. 165	116
8. <i>Heterostegina heterostegina praecostata</i> n. subsp., specimen with ornamentation in the centre, close to <i>Heterostegina costata levitesta</i> n. subsp., 12 ×, Niederleis, No. P. 164	116

c. Four populations from Neudorf on the March C.S.R. 100% smooth, adult specimens are similar to those from Prinzendorf (see text pl. 3, fig. 13). Small specimens are more abundant in lower strata and very

similar to thin-sections from Voeslau (see text pl. 3, fig. 8).

d. One population from Brunn near the Schneebergbahn, West of Wiener Neustadt. 95% smooth, 5% or-



TEXT PLATE 5

- Fig. 1 *Heterostegina* sp. cf. *Heterostegina papyracea gigantea* Seguenza, median section, megalospheric specimen, Tortonian, Retznei, Styria, No. P. 124
- Fig. 2 *Heterostegina* sp. cf. *Heterostegina papyracea gigantea* Seguenza, microspheric specimen, same locality, No. P. 123
- Fig. 3 *Heterostegina complanata spiralis* n. subsp., Holotype, median section, megalospheric specimen, Upper Miocene, Chania, Crete, Greece, No. P. 114.
- Fig. 4 *Heterostegina complanata sculpturata* n. subsp., Holotype, median section, megalospheric specimen, Neogene, Ramla Bay, near Suez, Egypt, No. P. 111
- Fig. 5 *Heterostegina complanata sculpturata* n. subsp., median section, megalospheric specimen, same locality, No. P. 110
- Fig. 6 *Heterostegina involutiformis* n. sp., median section, Saucats, France, No. P. 23
- Fig. 7a, b *Heterostegina involutiformis* n. sp., Holotype, external views, No. P. 161

namented. Sections similar to those of Prinzendorf. The accompanying fauna indicates *Bulimina-Bolivina* Zone.

A few populations from the Central Danube Basin, should be mentioned since they establish the identity of the species and indicate the possibility to correlate the detailed subdivision of the Tortonian.

a. Population Wildon, Styria, Austria, with predominating smooth specimens. The secondary septa are medium-sized, long secondary septa are rare.

b. Population Muehldorf in the Lavanttal, Carinthia, Austria. 63% smooth, 37% ornamented (12 with centrally located ornamentation). This population has mostly very small specimens with septa of a specialization intermediate to Voeslau and Raussnitz. This locality has been studied by Grill (1952) and has been dated as "Zone with arenaceous Foraminifera," confirmed by the study of *Heterostegina*s from the same locality.

c. Two populations from Kosteĵ, Roumania. From this locality very extensive collections are available. More than 1000 specimens were examined and the following percentages were obtained: 83 (79)% smooth, 17 (21)% ornamented. In both populations specimens with medium-sized secondary septa are predominant.

d. Population Lapugy, Roumania, 48% smooth, 52% ornamented (15% centrally ornamented). Median sections similar to Voeslau.

The population from Lapugy belongs evidently to the Upper Lagenid Zone. The collections from Kosteĵ come either from the very top of the Lagenid Zone or from the very base of the "Zone with arenaceous Foraminifera." This intermediate position is indicated by the statistical study of the population.

A small population from Konovice, Poland is probably derived from strata correlative with the Upper Lagenid Zone.

It seems, therefore, possible to establish correlations on the basis of different species of *Heterostegina*. Much is still to be done and very extensive collections are to be made in sequences which are known as well as those of the Vienna Basin in order to provide a firm basis for detailed correlation.

d. Rare planiform species of *Heterostegina*.

Heterostegina complanata spiralis, n. subsp.

Text plate 5, figure 3; plate 23, figure 1

Holotype: text plate 5, figure 3; No. P. 114.

Derivatio nominis: *spiralis* = on account of the thick spiral.

Locus typicus: Chania, Crete, Greece.

Stratum typicum: Neogene, Upper Miocene or Lower Pliocene.

Test large, up to 10 mm in diameter, almost round in outline, surface smooth. A distinct thickening is

characteristic for this species. Embryonic chambers large: diameter of protoconch 0.2 mm; deutoconch: 0.25 mm broad, 0.33 mm. long. Primary septa strongly curved towards the apertural face of the specimen. Primary chambers 0.4-0.5 mm long, and subdivided by long secondary septa. Medium sized secondary septa only rarely present.

Occurrence: Type locality, in sandstones.

Remarks: Meneghini described (1857) the elementary species *Heterostegina complanata* from the Neogene of Sardinia. This species differs from our specimens in not having a spiral keel developed and having up to 4 smooth primary septa succeeding the protoconch. *Heterostegina complanata* differs from *Heterostegina costata* by higher developed secondary septa and more distinctly curved primary septa.

Heterostegina complanata sculpturata, n. subsp.

Text plate 5, figures 4, 5; plate 23, figure 4

Holotype: text plate 5, figure 5, No. P. 111.

Derivatio nominis: *sculpturatus* = ornamented.

Locus typicus: Ramla Bay near Suez, Egypt.

Stratum typicum: ? uppermost Miocene.

Medium sized, 6-8 mm in diameter; oval shaped with distinct ornamentation on the center of the test and along the primary septa in the younger part of the test. Median section shows great similarity with the previously described species. All the secondary septa fully developed and long.

Remarks: This species is closely related to *Heterostegina complanata spiralis* although it is impossible to decide yet which of the two species is the more specialized one. However the distinctly developed curvature of the primary septa and the smooth test together with the spiral keel suggest the possibility that the species from Crete is the more specialized one. Compared with the species-group of *Heterostegina costata* both species are more specialized than the most advanced species in the Vienna Basin.

The following features are therefore used to characterize the subspecies of *Heterostegina complanata* Meneghini:

Test smooth *Heterostegina complanata complanata* Meneghini

Test ornamented *Heterostegina complanata sculpturata* n. subsp.

Test smooth with spiral keel *Heterostegina complanata spiralis* n. subsp.

This species group might substitute *Heterostegina costata* in the Mediterranean but it is also possible that the species-group of *Heterostegina complanata* characterizes the Pliocene only and is a direct descendant of *Heterostegina costata*. Unfortunately nothing definite is known about the exact stratigraphic occurrence.

Heterostegina granulata *granulata*

Papp and Küpper

Plate 22, figures 1-5

1846 *Heterostegina costata* ORBIGNY p. 212 (pars), pl. 12, fig. 16 (non fig. 15).1952 *Heterostegina granulata* PAPP and KÜPPER, p. 7.

As the writers gave (1952) only a very short characterization of this species a complete description is here given.

Holotypus: Specimen figured by d'Orbigny (1846), pl. 12, fig. 16 (non fig. 15).

Derivatio nominis: *granulatus* = granulated; *testa* = test; on account of the granulated test.

Locus typicus: Nussdorf, Schreiberbach (Vienna XIX), Austria.

Stratum typicum: Tortonian, Upper Lagenid Zone.

Test evolute, 3-4 mm in diameter, with a very characteristic granulated ornamentation. This granulation is caused by very distinct pillar heads which are not only situated on the primary septa, but may be found also between them on the secondary septa. Small knobs not corresponding to pillar heads are evenly distributed between the septa. In the younger part of the test the septa can be traced by the arrangement of the ornamentation on the surface. In horizontal sections very small embryonic chambers are found. Diameter of protoconch: 0.05 mm. The first primary septa do not have secondary septa, the middle ones have 1 to 3 long secondary septa. The younger secondary septa have numerous long secondary septa. The primary septa are distinctly curved towards the apertural face of the test.

In the microspheric generation the embryonic chambers are only slightly smaller: diameter 0.03-0.04 mm. The spiral has more volutions in the centre, but in the younger part it is identical with the megalospheric generation. In the microspheric generation there are more primary septa without secondary ones (in total up to 16 in contrast to megalospheric generation with only 4-6). In the younger part of the test the septal arrangement is identical in both generations.

Occurrence: Tortonian, Upper Lagenid Zone: Nussdorf Schreiberbach (type locality) Rauchstallbrunngraben, Roemerberg both near Baden, Lower Austria. Lower Lagenid Zone: Niederleis, Lower Austria.

Remarks: *Heterostegina granulata* is a rare species in the Vienna Basin. Numerous specimens have only been found at the localities Roemerberg and Rauchstallbrunngraben. From Niederleis only a few specimens are available, characterized by a few medium-sized secondary septa on the earlier primary septa. The specimens from the Rauchstallbrunngraben and Roemerberg do not have any medium-sized secondary septa and are, therefore, more specialized than the population from Niederleis. The ornamentation is also slightly different in the various localities, but we are of the opinion that such differences are too insignificant to justify even subspecific separation.

Heterostegina granulata *praeformis*, n. subsp.

Plate 22, figures 6, 7

Holotype: Plate 22, figure 7, No. P. 160.

Derivatio nominis: *prae* = before; *forma* = form; form before the typical subspecies.

Locus typicus: Orthez, France.

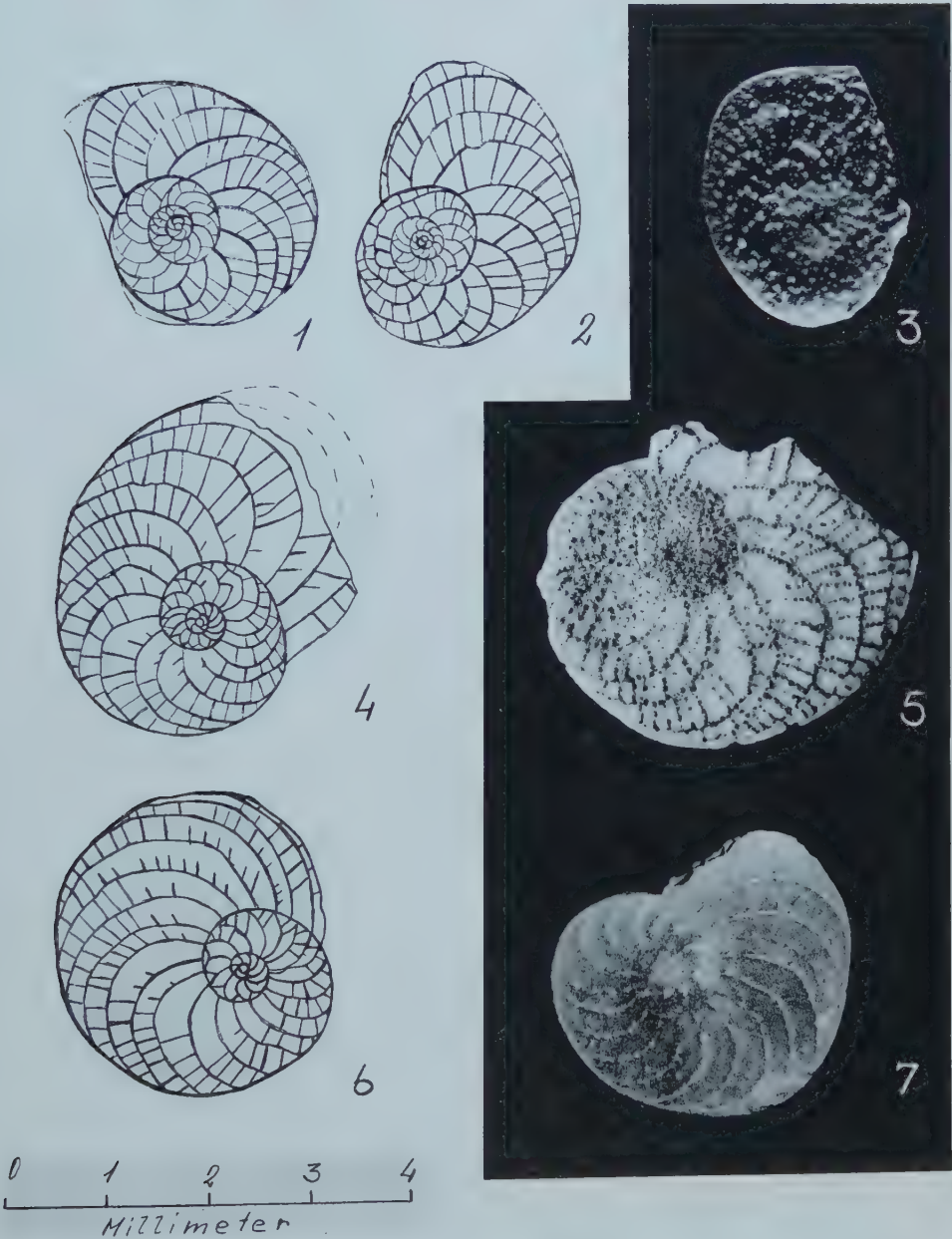
Stratum typicum: Helvetian.

Test evolute, small, 3 mm in diameter, ornamented, small embryonic chambers. Primary septa with 5-9 long, and 2-7 medium-sized secondary septa. The test has pillar heads concentrated mainly on the center; on the rest of the test they are generally restricted to the primary septa. There is less ornamentation than in the elementary species, and the number of medium-sized secondary septa is larger. All other features (as f. i. size of embryonic chambers) are identical.

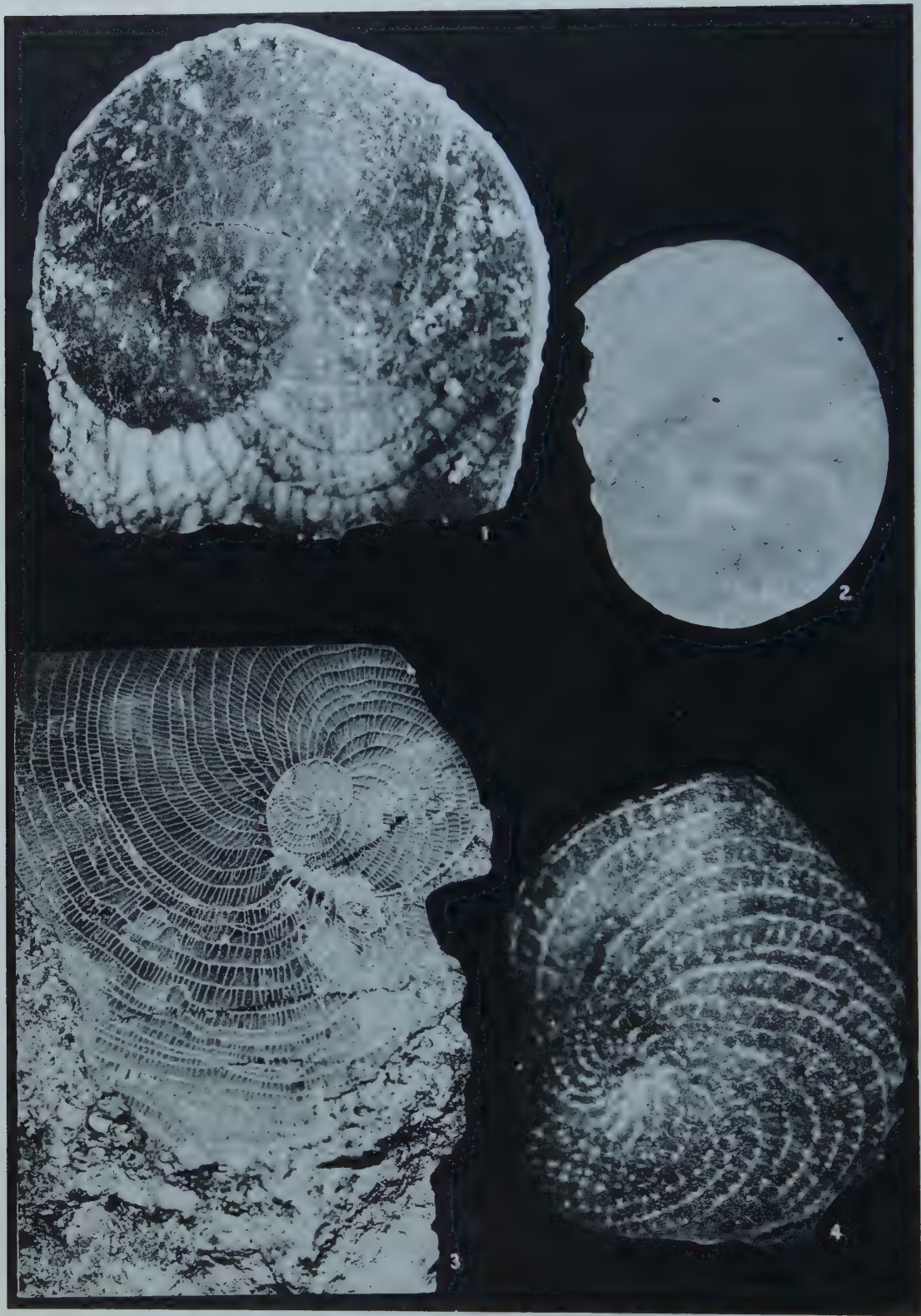
Remarks: The new subspecies is closely related to the population of Niederleis. Morphological differences indicate, however, that the population from Orthez is more primitive and ancestral of *Heterostegina granulata*. A subspecific differentiation is therefore justified since the subspecies are also separated by a considerable period of time.

EXPLANATION OF PLATE 22

FIGS.	PAGE
1. <i>Heterostegina granulata</i> <i>granulata</i> Papp and Küpper, Upper Lagenid Zone, Tortonian, Rauchstallbrunngraben near Baden, median section, megalospheric specimen, No. P. 120	122
2. <i>Heterostegina granulata</i> <i>granulata</i> Papp and Küpper, microspheric specimen, same locality, No. P. 121	122
3. <i>Heterostegina granulata</i> <i>granulata</i> Papp and Küpper, external view, same locality, 12 ×, No. P. 158	122
4. <i>Heterostegina granulata</i> <i>granulata</i> Papp and Küpper, median section, megalospheric specimen, Niederleis, No. P. 22	122
5. <i>Heterostegina granulata</i> <i>granulata</i> Papp and Küpper, external view, Niederleis, 12 ×, No. P. 159	122
6. <i>Heterostegina granulata</i> <i>praeformis</i> n. subsp., median section megalospheric specimen, Helvetian, Orthez, France, No. P. 21	122
7. <i>Heterostegina granulata</i> <i>praeformis</i> n. subsp., Holotype, external view, Helvetian, Orthez, France, No. P. 160	122



Papp and Küpper: *Heterostegina* in the European Upper Tertiary



Papp and Küpper: *Heterostegina* in the European Upper Tertiary

From the Miocene of Spain (?Burdigalian), 250 m South-East of Castellez between Barcelona and Tarragano a population has been studied showing numerous smooth specimens of which 15% are identical with those from Orthez. As the stratigraphic position is rather dubious and the specimens not very well preserved, a detailed description is not yet possible.

Heterostegina granulata *testa praeformis* has also been observed at Varpalota, Hungary. This locality, according to its molluscan fauna (see A. Papp 1952), is Upper Helvetian in age.

The general evolution of *Heterostegina granulata* *testa* indicates that this group originates in the Lower Miocene where it is represented by populations with smooth tests and a rather well developed system of

secondary septa. In the Helvetian the group is represented by *Heterostegina granulata* *testa praeformis* and in the Tortonian by the typical subspecies. Unfortunately this species-group is rather rare, and there are no populations available earlier than Helvetian. The occurrence in Hungary, Austria and France, however, shows the wide distribution of this species in Europe.

Heterostegina sp. cf. Heterostegina papyracea gigantea Seguenza

Text plate 5, figures 1, 2; plate 23, figure 3

1880 *Heterostegina papyracea* var. *gigantea* SEGUENZA p. 56, pl. 7, fig. 2.

1933 *Heterostegina gigantea* DAVID, p. 125, pl. 8, figs. 3a, b.

Stratigraphic distribution:		Species:	<i>Operr. complanata</i>	<i>H. heterostegina</i>	<i>H. heterostegina praeformis</i>	<i>H. costata levitesta</i>	<i>H. costata costata</i>	<i>H. costata politatata</i>	<i>H. costata corinata</i>	<i>H. granulata</i> <i>testa praeformis</i>	<i>H. granulata</i> <i>testa granulata</i>	% of Specimens with ornamentation.	% of smooth specimens.	Predominant number of smooth (operculine) septa in the species group <i>H. costata</i> s.l.
TORTONIAN.	Rotalia-Zone													
	Bulimina- Bolivina Zone											1-10	90-99	0 - 3
	Zone with arenaceous foraminifera.											5-40	60-95	1 - 4
	Upper Logenid Zone											50-85	15-50	2 - 6
	Lower Logenid Zone											40	60	3 - 9
HELVETIAN.												?	?	?
BURDIGALIAN.												±5	±95	4 - 10
AQUITANIAN.														

TABLE 1

Distribution of species and subspecies of the species-groups *Heterostegina costata* and *Heterostegina granulata* *testa* in the Upper Tertiary of Europe

EXPLANATION OF PLATE 23		PAGE
FIGS.		
1.	<i>Heterostegina complanata spiralis</i> n. subsp., Upper Miocene, 12 ×, Chania, Crete, Greece	121
2.	<i>Heterostegina costata levitesta</i> n. subsp., typical specimen without ornamentation, Tortonian, 12 ×, Kostej, Roumania.	116
3.	<i>Heterostegina</i> sp. cf. <i>Heterostegina papyracea gigantea</i> Seguenza, broken specimen, 12 ×, Retznei, Styria, No. P. 162.	123
4.	<i>Heterostegina complanata sculpturata</i> n. subsp., Neogene, Ramla Bay near Suez, Egypt	121

Test exceptionally large for a species of this genus. Diameter 23-25 mm; rather thin: 0.5 mm in the centre of the test where the maximum thickness has been measured. Because of the size of the test the specimens are not strictly as plane as most of the smaller species of this genus. The margin is often undulated. Between the primary septa several long and medium-sized secondary septa appear. The primary septa are distinctly curved towards the apertural face and have almost a semicircular outline. The embryonic chambers are small, diameter 0.14 mm in megalospheric specimens, with a very tightly coiled center (see text pl. 5, figs 1, 2). The configuration of the septa is pictured on plate 23, fig. 3.

Occurrence: Tortonian: Hannersdorf, Burgenland; Retznei, Styria. The sediment in both localities is an algal limestone, the so-called "Leithakalk." The species differs from all other *Heterostegina*s by the size of the test alone and the very small embryonic chambers. It cannot be related to any of the other species-groups described above.

The species described by Seguenza is very similar to our specimens, and was found originally in the Aquitanian of Italy. It has also been reported from the Burdigalian of Syria. Notwithstanding the differences in age our specimens are so similar that an approximate determination (cf.) seems to be justified. A few specimens with medium sized secondary septa were noticed in our populations.

INVOLUTIFORM SPECIES OF *HETEROSTEGINA*

Heterostegina involutiformis n. sp.

Text plate, figures 6, 7a b

1932 *Heterostegina* cf. *depressa* TAN SIN HOK p. 136, pl. 1, figs. 7-9.

Holotype: Text plate 5, figures 7a, b, No. P. 161.

Derivatio nominis: on account of the involute test.

Locus typicus: Saucats near Dax, France.

Stratum typicum: Upper Burdigalian.

Test small, 2.5 mm, with a distinct umbonal thickening. The surface has in the center a distinct granulation on the outside of the younger part of the test; septa are distinctly visible. In median section very convex primary septa are present. In the younger part of the test the distance between two succeeding primary septa is 0.2 mm. The embryonic chambers are small, diameter of the protoconch: 0.1 mm.

Occurrence: Saucats near Dax, France, "faluns supérieurs," (Upper Burdigalian).

Remarks: This species is represented by only 9 specimens. All specimens have a distinct umbonal thickening to the involution of the test. Some of them hardly show any ornamentation. Tan Sin Hok described in 1932 a similar species as *Heterostegina* cf. *depressa* Orbigny from the lower Oligocene (Upper

Lattorfian) and noted that this species had a stratigraphic range from Eocene to recent. He apparently identified the Eocene species with *Heterostegina depressa* and came to the conclusion that it has a wide stratigraphic distribution. Unfortunately we do not have recent material available to compare our material. At present we can state that the only difference between recent and fossil specimens is in the lack of ornamentation in recent specimens. The fauna of Saucats, which contains *Miogyopsina* is so far the only locality in the Tertiary of Europe known to us with involute *Heterostegina*s. In the Near East and in tropical regions, however, they become very abundant.

This species has always been identified as *Heterostegina depressa* Orbigny, described and figured by d'Orbigny as distinctly evolute (see d'Orbigny's type figure). It can, therefore, not be identified with involute specimens. All specimens figured, for instance by Cushman, as the genotype of *Heterostegina* are not identical with this species. The difference between involute and evolute species is apparently of great taxonomic importance because intergradations of these types have so far not been observed in any populations.

STRATIGRAPHIC VALUE OF THE *HETEROSTEGINA*S

In the Aquitanian of France populations with *Operculina complanata* (Defrance) are common. In populations of Aquitanian and Burdigalian age an increasing percentage of *Heterostegina heterostegina heterostegina* (Silvestri) was found. In the Helvetian of Italy the same species has been recorded, differing from older populations in a slightly higher specialization of the secondary septa, however not distinct enough to warrant subspecific differentiation of the older populations.

In the lowermost Tortonian of the Vienna Basin populations differ already substantially so that a subspecific differentiation is imperative. They consist mainly of *Heterostegina heterostegina praecostata*. Numerous populations are available from other zones of the Tortonian consisting of different subspecies of *Heterostegina costata* s. l. A comparison and combination of all the different populations indicates a complete bioseries. This bioseries allows the same stratigraphic subdivision of the Tortonian as established by R. Grill on the base of faunal assemblages and by Papp and Turnovsky with the help of the bioseries of *Uvigerina*. The stratigraphic distribution of the different species is given on table 1, and the change of sculpture in time is compiled on table 2.

Although not occurring very abundantly it was possible to establish a similar though less complete bioseries for the species-group of *Heterostegina granulata-testa* Papp and Küpper. *Heterostegina granulata-testa praeformis* was found in Saucats, France and in Varpalota, Hungary, both localities Helvetian in age.

The populations from the Lower and Upper Lagenid Zone are slightly different but they were not separated taxonomically because the differences are not very great. In conclusion species of *Heterostegina* are apparently valuable for correlation if sufficient attention is paid to evolutionary processes. The Helvetian-Tortonian boundary as used in the Vienna Basin corresponds with the same boundary in France, Italy and

Hungary based on megafossil evidence.

The other species listed are rare and incompletely known in their evolution, and, therefore, of less stratigraphic importance. Their presence indicates, however, that the genus *Heterostegina* is very complicated and polyphyletic as already shown by Glaessner (1947).

It is of importance to note that the morphological changes are certainly not due to different facies be-

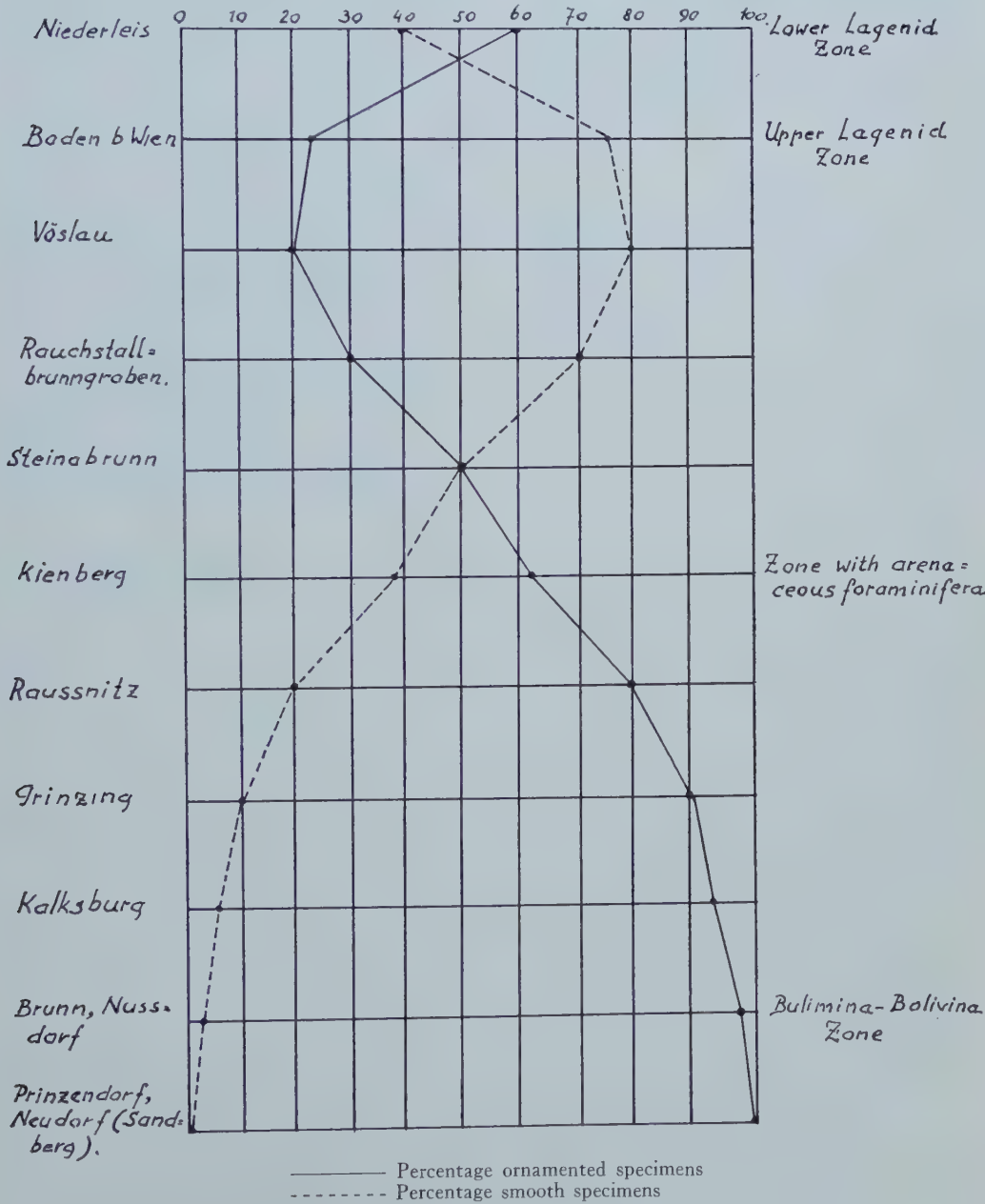


TABLE II

Change of percentage of ornamented specimens in superimposed populations from the Vienna Basin

cause many populations of exactly the same age have been found in the most different facies. The specialization of a population cannot be determined by the study of only a few specimens. In many instances a single specimen may have a specialized ornamentation and a primitive development of secondary septa. In larger populations these differences can be accounted for by the study of percentages.

The theoretical interpretation of an almost identical example of evolution, the genus *Cycloclypeus* has excellently been presented by Tan Sin Hok (1932). Since our observations on *Heterostegina*s indicate identity of the evolutionary process, reference is made to Tan Sin Hok's monograph.

RESULTS

The genus *Heterostegina* in the Upper Tertiary of Europe is described. A morphogenetic analysis demonstrates the usefulness of this group for stratigraphical purposes. It became necessary to give a new definition for the genera *Heterostegina* and *Operculina*, and to subdivide the genus *Heterostegina*. The following species and subspecies were described in detail:

Heterostegina heterostegina heterostegina (Silvestri)

Heterostegina heterostegina praecostata n. subsp.

Heterostegina costata levitesta n. subsp.

Heterostegina costata costata Orbigny

Heterostegina costata politatista n. subsp.

Heterostegina costata carinata n. subsp.

The first listed species is directly and intimately related to *Operculina complanata* (Defrance). The species group of *Heterostegina costata* is characteristic for Central Europe. From the Mediterranean the following species were discussed:

Heterostegina complanata complanata Meneghini

Heterostegina complanata spiralis n. subsp.

Heterostegina complanata sculpturata n. subsp.

The representatives of this species group substitute the species-group of *Heterostegina costata* in the Mediterranean, although it is probable that they are younger and phylogenetically related.

The following rare species were discussed:

Heterostegina granulata testa granulata testa Papp and Küpper.

Heterostegina granulata testa praeformis n. subsp.

Heterostegina sp. cf. *Heterostegina payracaea gigantea* Seguenza

One involutiform species of *Heterostegina* is recorded from the Miocene of Europe:

Heterostegina involutiformis n. sp.

In stratigraphic respect the genus *Heterostegina* proved to be of great interest and value because even a correlation of detailed stages is possible if suitable material (populations) is available. This paper gives more detailed information about the genus *Heterostegina* than was previously available but should be regarded only as a beginning.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
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112. TYPICAL FORAMINIFERAL HORIZONS
IN THE LOWER CRETACEOUS OF COLOMBIA, S. A.

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ABSTRACT—Four foraminiferal levels are discussed: The *Choffatella* assemblage which is typical for the Uppermost Hauterivian (to Lowermost Barremian?), *Epistomina mosquensis* Uhlig probably typical for the Barremian, *Orbitolina* ex gr. *concava texana* (Roemer) for the lower Middle (to Lower?) Albian, and *Haplostiche texana* (Conrad) for the Upper Albian.

INTRODUCTION

The writer gratefully acknowledges the permission of International Petroleum Company (Intercol) to publish this paper. E. Hubach, director of the Instituto Geológico Nacional de Colombia granted permission to use the material of Los Santos and H. Buegl from the same Instituto furnished information on this locality and on its age. Richmond Petroleum Company and Texas Petroleum Company gave permission for publishing the data on wells Culimba No. 1 and Tetuan No. 1 respectively. The geological information on surface localities of Intercol was obtained from unpublished Company reports by H. F. Belding, C. Chenevart, J. W. Durham, O. L. Haught, J. A. Nugent, D. J. Podesta, and J. W. Robbins.

Foraminifera are scarce and for the most part undiagnostic in the Lower Cretaceous of Colombia. Accumulations of Miliolidae in massive limestones of Barremian to Middle Albian age in the Ranchería and Cesar valleys (northeastern Colombia) are facies indicators for littoral or back reef shoals and are not time markers.

However, a few Lower Cretaceous foraminiferal assemblages are typical for restricted time intervals in Colombia. They correspond, in many cases, to levels of their greatest abundance in other parts of the world, although there their total range might be wider.

BIOSTRATIGRAPHIC NOTES

CHOFFATELLA ASSEMBLAGE

Faunas which carry *Choffatella decipiens* Schlumberger, *Ch. sogamosae* (Karsten) or *Pseudocyclammina rugosa* (Orbigny) are considered as belonging to the same assemblage. The close association of the two genera is described by W. Maync (1949, p. 80) and L. Jordan and E. R. Applin (1952, p. 3) from Venezuela and from the southern United States.

Occurrences

Locality No. 7.—(Text figure 1). In the Rio Maracas, an eastern tributary of the Rio Cesar, 13,100 m N

68° E of the town of Becerril; Department of Magdalena.

Choffatella decipiens Schlumberger is found in calcareous bands which are intercalated in white to gray, locally reddish sandstones of the uppermost levels of the Rio Negro formation.

Locality No. 9.—(Text figure 1). In Caño Sucio, 5 km east of the town of Castilla, immediately upstream from bridge on Ayacucho-Peinitas road; Department of Magdalena.

Choffatella decipiens Schlumberger, *Nodosaria* sp., *Gumbelina* sp., echinoid and mollusk remains, and coprolites occur in limestones at the base of the Rosa Blanca formation¹ near the contact with the Rio Negro formation.

Locality No. 11.—(Text figure 1). In Quebrada Las Peñitas, an eastern tributary of Quebrada Santa Inés, 6,500 m S 75° E of the town of Totumal; Department of Magdalena.

Choffatella decipiens Schlumberger, *Nodosaria* sp., *Robulus* sp., bryozoa and echinoid spines occur with *Pholadomya robinaldina buchiana* (Karsten), and other pelecypoda in yellow to gray shales with bands of argillaceous limestone. These overlie a reddish pebbly sandstone and form the uppermost levels of the Rio Negro formation (text figure 2a). The Rio Negro formation is overlain to the west by thick bedded limestones of the Rosa Blanca formation. The lowermost ten meters of this Rosa Blanca also contain *Choffatella decipiens* Schlumberger, bryozoa and large pelecypoda (text figure 2a).

Locality No. 15.—(Text figure 1). Well Totumal No. 3 and other wells drilled by International Petroleum (Colombia) Ltd. in the area near Aguachica; Department of Magdalena.

Choffatella decipiens Schlumberger, bryozoa, mollusk and echinoid remains, and calcareous algae occur at the base of the Rosa Blanca and at the very top of the Rio Negro formations.

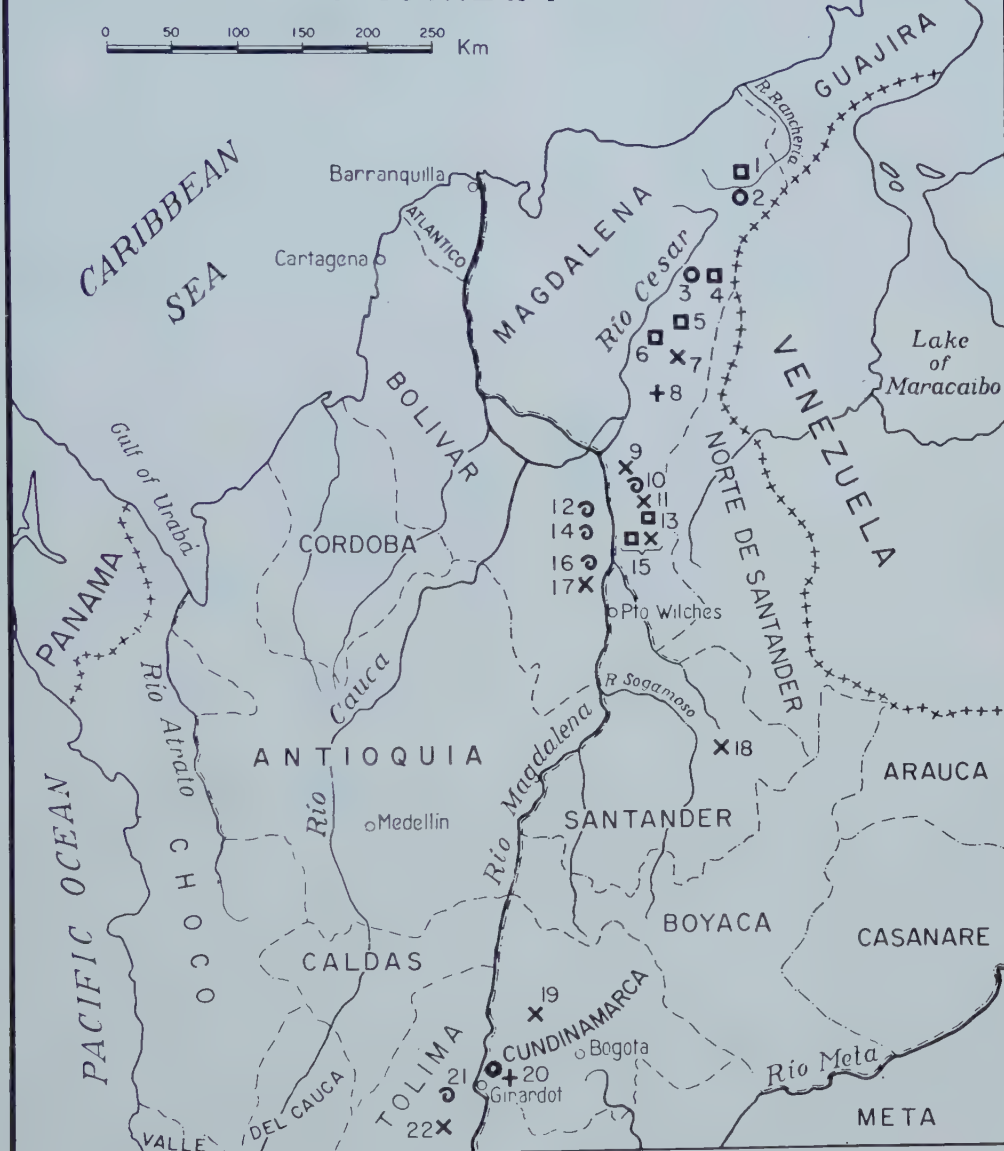
Locality No. 17.—(Text figure 1.). Well Culimba No. 1 (Richmond Petroleum Company), about 27 km N 20° W of the town of Puerto Wilches; Department of Bolívar.

Choffatella sogamosae (Karsten) occurs in a lime-

¹ This and most of the other formational names of this paper are unpublished names used by International Petroleum (Colombia) Ltd.

MAP OF COLOMBIA

0 50 100 150 200 250 Km



FOSSIL LOCALITIES

- (1) WELL PAPAYAL #1
- (2) TRAGA ENTERO
- (3) MANAURE WEST
- (4) MANAURE EAST
- (5) CASACARA
- (6) WELL MARACAS #1

- (7) RIO MARACAS
- (8) CAÑO LA ROYA
- (9) CAÑO SUCIO
- (10) Q. PERALONZO
- (11) Q. LAS PENITAS
- (12) Q. SAN MIGUEL
- (13) Q. AGUA BLANCA
- (14) ARENAL

- (15) WELL TOTUMAL #3
- (16) SIMITI
- (17) WELL CULIMBA #1
- (18) LOS SANTOS
- (19) VILLETA
- (20) APULO
- (21) RIO COBRE
- (22) WELL TETUAN #1

+ EPISTOMINA FAUNA
X CHOFFATELLA FAUNA

○ ORBITOLINA FAUNA
◻ HAPLOSTICHE FAUNA

⊙ MEGAFOSSELS ONLY

Fig. 1

stone section at 2,020', five feet above the pre-Cretaceous (text figure 2b).

Locality No. 18.—(Text figure 1). In bend of road which leads from the town of Los Santos to the gypsum mine El Diamante, 1,400 m N 77° W of the town; Department of Santander.

This locality was discovered by H. Buergl of the Instituto Geológico Nacional. *Choffatella sogamosae* (Karsten) occurs in a white to yellowish soft marl.

Locality No. 19.—(Text figure 1). Immediately west of sharp road bend around the Cuchilla de Totumito, 1,500 m N 83° W of the town of Villeta on road to Guaduas; Department of Cundinamarca.

Choffatella sogamosae (Karsten) occurs in light gray to yellow siltstones, gray shales, and thin bands of bluish gray (in part sandy) limestones, a few meters beneath the bottom of the Paja formation (Text figure 2c).

Locality No. 22.—(Text figure 1) Well Tetuan No. 1 (Texas Petroleum Company) 4,300 m S 34° W of the town of Ortega; Department of Tolima.

Anomalina sp. aff. *A. plummerae* Tappan, *Choffatella decipiens* Schlumberger, *Gaudryina* sp. ?, *Neobulimina* sp. aff. *N. canadensis* Cushman and Wicken, *Pseudocyclammina rugosa* (Orbigny), *Robulus* sp., *Rotalia* sp., *Saracenaria* sp., ostracoda and echinoid

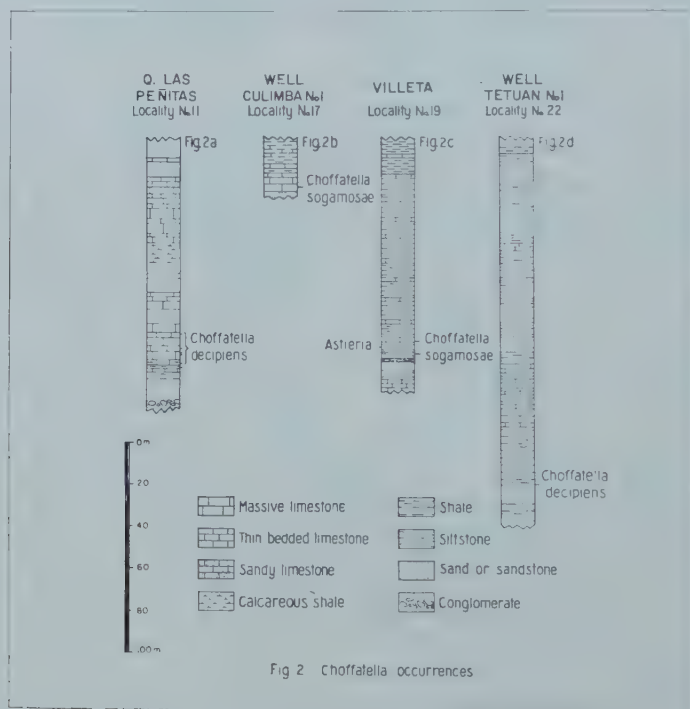


Fig. 2 *Choffatella* occurrences

remains are found in calcareous shales of a core from 4,510 to 4,520' depth, about 30' above the pre-Cretaceous (text figure 2d).

Age and stratigraphic position of the *Choffatella* assemblage

Columbia.—The Hauterivian ammonite *Astieria* sp. is found in the *Choffatella* bearing beds in Villeta (locality No. 19). Somewhat higher in section occur the Barremian ammonites *Nicklesia* sp., and *Pulchellia* sp.

H. Buergl (verbal communication) reports *Lissonia* sp., *Cucullaea dilatata* Orbigny, *Exogyra boussingaulti* Orbigny, and *Toxaster roulini* Agassiz together with *Choffatella sogamosae* (Karsten), and the Barremian ammonites *Pulchellia galatea* (Karsten), and *P. cf. hispanica* (Hyatt) from 20 m higher in the section from Los Santos (locality No. 18), thus proving an Upper Hauterivian age for this locality.

A lowermost Barremian (?) to Upper Hauterivian age of the Rio Maracas locality (No. 7) is suggested by the presence of the Barremian *Nicklesia* sp. and *Pseudohaploceras* sp., 65 and 45 m respectively above the top of the Rio Negro formation in Caño La Roya, 1,900 m S 19° W of the town of Palmita (text figure 1, locality 8).

A lowermost Barremian (?) to Upper Hauterivian age for the Caño Sucio locality (No. 9), Quebrada Las Peñitas (No. 11), and for the *Choffatella* horizon of Well Totumal No. 3 (No 15) is evidenced by the following: 1) The Rosa Blanca formation contains the Barremian ammonite *Pseudohaploceras incertum* Riedel (erroneously spelled *Pleurohaploceras* by Riedel, 1938) 60 m above its base in Quebrada Peralonzo (locality No. 10, 6 km S 20° E of locality No. 9). 2) *Crioceras* sp. ind. is found at the very base of the Rosa Blanca formation in Quebrada San Miguel (lo-

cality No. 12, 12 km N 34° W of the town of Morales). 3) The Barremian marker *Nicklesia* sp. occurs in the Rosa Blanca, 2,300 m from Arenal on the trail leading west (locality No. 14), while *Nicklesia* sp., *Pulchellia* sp. and *Karstenia* sp. are found 47 m above the base of the Rosa Blanca at the southwestern corner of the Ciénaga Simití 2 km south of the mouth of Quebrada Blanquise (locality No. 16).

Evidence on the exact age of the *Choffatella* assemblage in well Tetuan No. 1 (locality No. 22) is less satisfactory. The corresponding level in outcrop contains only mollusks with wide ranges. In the Rio Cobre (text figure 1, locality No. 21), 120 m above the beds which are foraminiferal in the well, occur the Lower Aptian to Barremian ammonite *Ancylloceras* sp. associated with *Cardita* (*Venericardia*) *neocomensis* Orbigny, *Corbis corrugata* Sowerby, *Ptychomya robinaldina buchiana* (Karsten), etc. This fauna in turn is overlain by the Upper Aptian assemblage of *Chelonicer* sp., *Parahoplites* sp., *Cymatoceras colombianus* Durham, *Heminautilus etheringtoni* Durham, *Cuculaea gabrielis* Leymerie, etc. Thus, the available megafossils suggest Lower Aptian as the upper age limit for the *Choffatella* level in Tetuan. There is no direct fossil evidence for a lower limit.

A Barremian to Upper Hauterivian age can be inferred for the Culimba locality (No. 17) from the position of the fauna immediately above the pre-Cretaceous.

Summarizing, it can be stated that the *Choffatella* assemblage occurs in Colombia a short distance below the lowest Barremian ammonites, wherever sufficient megafossil control is available (in five out of eight cases). In two cases an Uppermost Hauterivian age is definitely established. In one case it could be as young as Lower Aptian. The *Choffatella* assemblage spread from the Venezuelan border to the Upper Magdalena valley, over a distance of about 650 km, at the end of Hauterivian (to the beginning of Barremian?) time.

The position of the *Choffatella* level is remarkably persistent in time. However it changes its position in the lithologic column from the bottom of the basal marine Cretaceous limestone and clastics in the north and south to near their top in the central part of the area. This suggests a slight crossing of time lines by the formational boundaries.

Outside of Colombia.—Megafossil control on the exact age of the lowest occurrence of *Choffatella* is less satisfactory in Venezuela than in Colombia. W. Maync (1949, p. 543) suggests an age from Barremian or older to Aptian. E. Rod and W. Maync (1954, p. 279) consider *Choffatella decipiens* as "hitherto restricted to formations of Aptian age." E. Mencher et al. (1953, p. 774) assume an age hardly older than Aptian for most of the *Choffatella*-bearing formations. Findings in Colombia, especially those near the Venezuelan border (localities Nos. 7 and 9) suggest that

the bottom of the Apón and Tomón formations of Venezuela are of Lowermost Barremian to Upper Hauterivian age. Higher levels of *Choffatella* are associated with *Orbitolina* ex gr. *texana* (Roemer) in Venezuela (Maync 1949, p. 543; Rod and Maync 1954, p. 277) and in the southern United States (Jordan and Applin 1952, p. 2). This suggests that further research may reveal their presence in definitely Barremian and Aptian beds in Colombia also.

EPISTOMINA MOSQUENSIS ASSEMBLAGE

Occurrences

Locality No. 8.—(Text figure 1). In Caño La Roya, 1,900 m S 19° W of the town of Palmita; Department of Magdalena.

Epistomina mosquensis Uhlig is found in a shaly limestone of the Rosa Blanca formation, 65 m above its base (text figure 3a).

Locality No. 20.—(Text figure 1). 1,200 m S 18° W from cement plant El Diamante, on the Apulo-Viotá road; Department of Cundinamarca.

Epistomina mosquensis Uhlig occurs in reddish and black shale with siltstone concretions and bands of fossiliferous limestone, about 190 m above the bottom of the Paja formation (text figure 3b).

Age and stratigraphic position of the

Epistomina mosquensis assemblage

The Barremian ammonite *Nicklesia* sp. occurs in the same sample as *Epistomina mosquensis* Uhlig in Caño La Roya (locality No. 8). The foraminiferal fauna from Apulo falls, from its position, in the Barremian. The species may deserve some attention as a marker, pending further investigation. It is known from two localities only. But they are of the same age although of different lithology and 570 kilometers apart.

ORBITOLINA CONCAVA TEXANA ASSEMBLAGE

J. W. Durham studied the occurrences of this fossil in Colombia and stressed its stratigraphic value in unpublished Company reports.

Occurrences

Locality No. 2.—(Text figure 1). In Quebrada Traga Entero, 10 km east of the town of Fonseca; Department of Magdalena.

Orbitolina ex. gr. *conca* *texana* (Roemer) occurs about 45 m above the base of the Aguablanca formation in thinly bedded limestone (text figure 3c).

Locality No. 3.—(Text figure 1). On road to La Paz, 2 km W of the town of Manaure; Department of Magdalena.

Massive to well bedded limestones 70 m above the bottom of the Aguablanca formation and 3 m above a bed with giant *Nerinea* contain *Orbitolina* ex. gr. *conca* *texana* (Roemer) (text figure 3d).

Locality No. 20.—(Text figure 1). On private road about three km W of Apulo Cement Factory; Department of Cundinamarca.

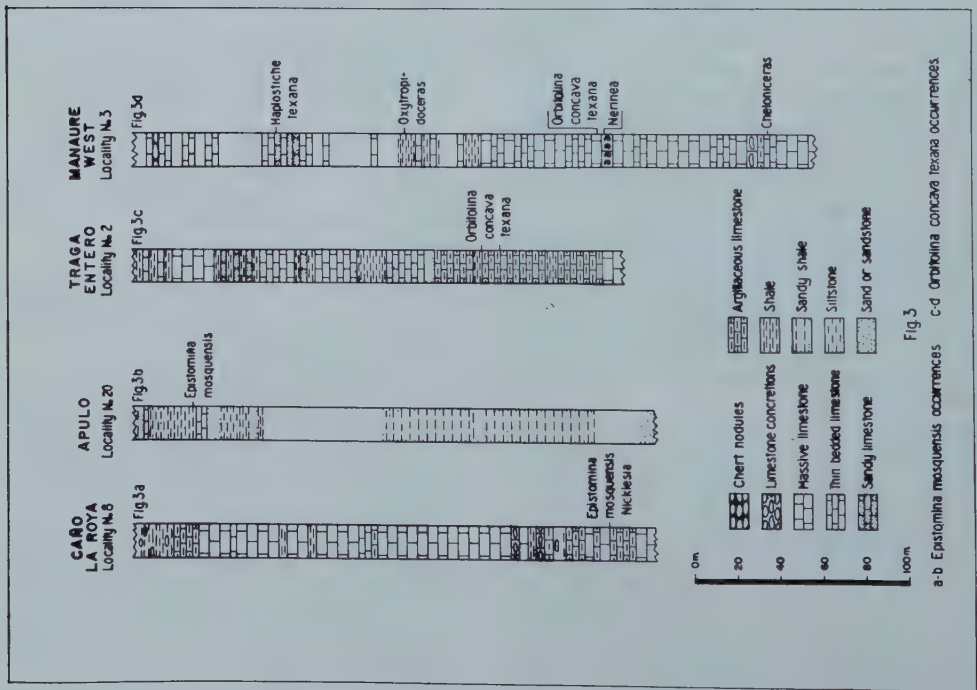


Fig. 3
a-b *Epistominia masquensis* occurrences c-d *Orbulina concava texana* occurrences

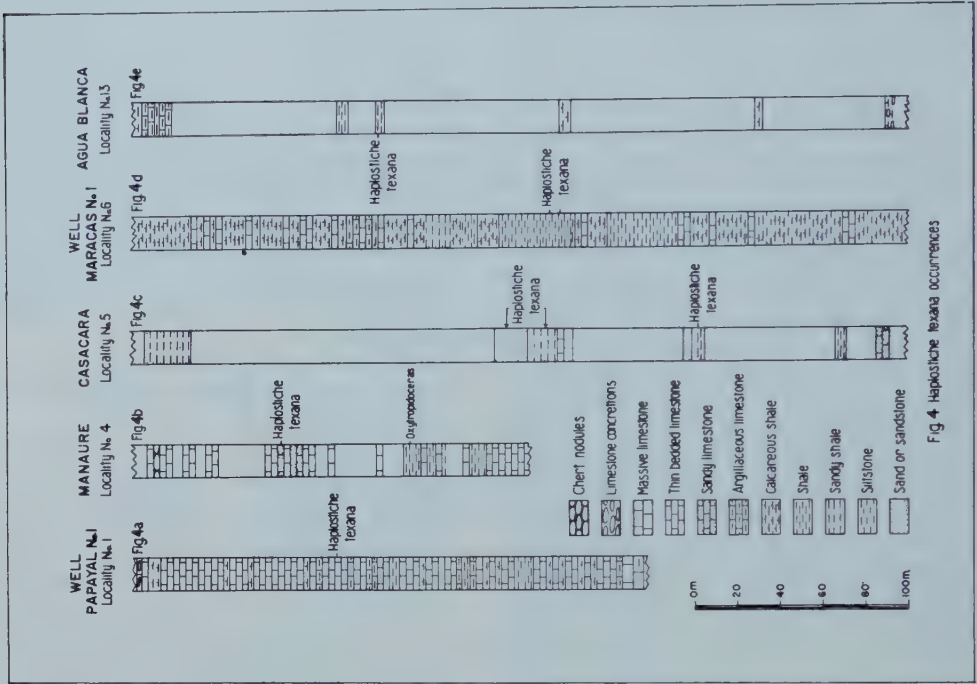


Fig. 4 *Haplostiche texana* occurrences

J. M. Dorreen encountered orbitoidal foraminifera, probably *Orbitolina* ex. gr. *concava texana* (Roemer) in a thin calcareous interbed in black non-calcareous shale. *Chelonicer* was noted a short distance (~100 m) below the foraminifera, while *Oxytropidoceras* was found higher in the section.

*Age and stratigraphic position of
Orbitolina concava texana*

The Lower Albian to Aptian *Chelonicer* was found 80 m below the foraminifera in the Manaure section (locality 3). *Oxytropidoceras* sp. which is most common in the upper Middle Albian occurs 60 m above *Orbitolina* (text figure 3d). In Apulo it appears a short distance below *Oxytropidoceras*. This places the foraminifera level in the lower Middle (to Lower) Albian. The fauna spread over a distance of 650 km in Colombia.

L. W. Stephenson et al. (1942, chart 9) limit *Orbitolina texana* (Roemer) s.l. in the Gulf Coastal region to the interval between the very top of the Aptian and the lower Middle Albian. Maync (1942, p. 543) and Imlay (1944, chart 10a) extend the range somewhat deeper into the Upper Aptian. In Texas it is most abundant in the upper Middle Albian part of the Glen Rose formation which lays above *Douvillei-ceras*-bearing beds, according to Sellards et al. (1932,

p. 317). The three Colombian occurrences are only slightly older.

HAPLOSTICHE TEXANA ASSEMBLAGE

C. D. Redmond, formerly with Tropical Oil Company, first noticed the stratigraphic importance of this species in Colombia.

Occurrences

Locality No. 1.—(Text figure 1). Well Papayal No. 1 (Cravo Oil Company) on the Rio Hacha highway, 1,900 m N 41° W of the town of Papayal; Department of Magdalena.

Gray finely crystalline limestones in a core from 788-795' depth from the upper third of the Aguablanca formation contain *Haplostiche texana* (Conrad), bryozoa, mollusk and echinoid remains (text figure 4a).

Locality No. 4.—(Text figure 1). On road to town of La Paz, 1,600 m W of Manaure; Department of Magdalena.

Ammobaculites goodlandensis Cushman and Alexander, *Cibicides* sp., *Discorbis minima* Vieaux, *Haplophragmoides concava* (Chapman), *Haplostiche texana* (Conrad), *Trochammina* sp., and ostracods are found in a sandy limestone 50 m below the top and 100 m above the bottom of the Aguablanca formation (text figure 4b).

Locality No. 5.—(Text figure 1). In Rio Casacará,

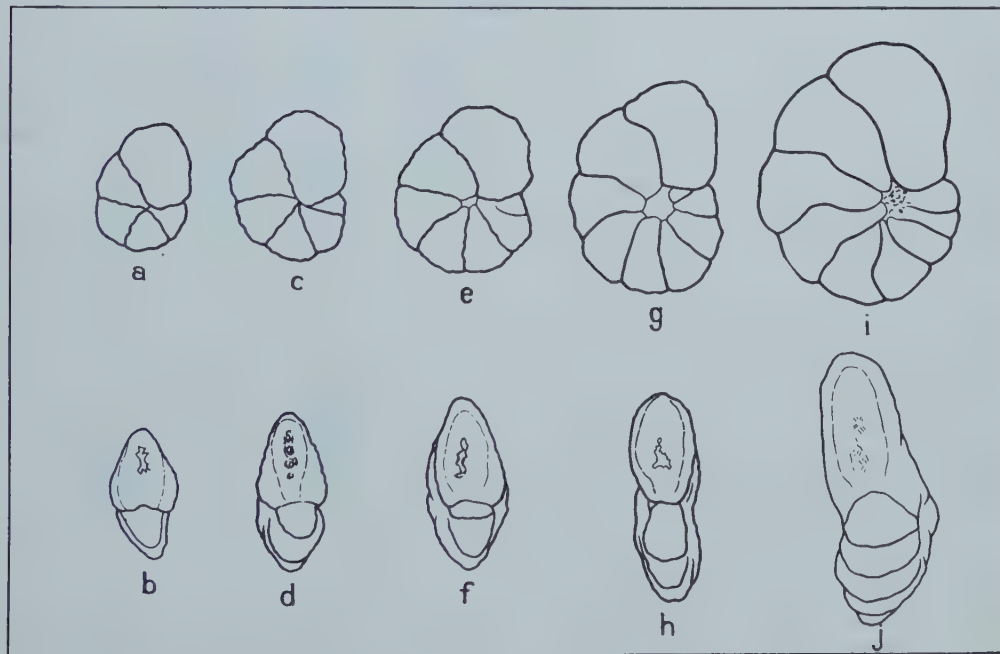


Fig 5

Figs. 5a-j *Choffatella sogamosae* (Karsten), entirely coiled specimens, locality No. 18, Upper Hauterivian, 14×. The upper line shows the relationship between increasing number of chambers (from five in figure a to nine in figure i) and increasing size. The lower line shows the same specimens in apertural view indicating the changing relationship between height-width index and size of the test.

5 km upstream from the bridge of the Becerril-Codazzi highway on the south bank of the southern arm of the river. The fauna is found over a distance of 60 m downstream from where the river splits into several arms.

Haplostiche texana (Conrad) and a small foraminiferal fauna occurs in soft fine glauconitic sandstones and shales from about 60 to 170 m below the top and 180 to 80 m above the bottom of the Tocuy formation (text figure 4c).

Locality No. 6.—(Text figure 1). Well Maracas No. 1, International Petroleum (Colombia) Ltd., 15 km N 65° W of the town of Becerril; Department of Magdalena.

Cuttings of partly glauconitic shale in the middle third of the Tocuy formation carry *Haplostiche texana* (Conrad) and a few arenaceous foraminifera (text figure 4d).

Locality No. 13.—(Text figure 1). In Quebrada Aguablanca, 7,500 m S 55° E of the town of Totumal; Department of Magdalena.

Haplostiche texana (Conrad) and *Ammobaculites* sp. occur in a gray and yellow mottled shale of the Middle Shale formation (text figure 4e).

Locality No. 15.—(Text figure 1). Well Totumal No. 3 [International Petroleum (Colombia) Ltd.], about 11 km southwest of locality No. 13; Department of Magdalena.

Haplostiche texana (Conrad), echinoid remains, and microgastropoda occur in the lower three fifths of the Middle Shale formation.

*Age and stratigraphic position of the
Haplostiche texana assemblage*

The Upper Albian *Pervinqueria* sp., found in the deeper part of the Tocuy formation on the highway 2,200 m north of the town of Becerril suggests the same age for localities No. 5 in the Rio Casacará and No. 6 in well Maracas No. 1. The same ammonite and *Brancoceras* sp. are found in and immediately above the Middle Shale formation on the Ciénaga Simití (near locality No. 16) suggesting an Upper Albian age also for localities Nos. 13 and 15 in Quebrada Aguablanca and in well Totumal No. 3. *Haplostiche texana* (Conrad) from Manaure (locality No. 4) is not accompanied by megafossils. The same stratigraphic level in nearby sections falls 80 m above an occurrence of the Upper to upper Middle Albian ammonite *Oxytropidoceras* sp.

Concluding, it can be said that sufficient megafossil evidence places the *Haplostiche texana* level, as described here from Colombia, in the deeper part of the Upper Albian in at least five out of six localities. The species occurs in the same time interval in limestone, shale and sand over a distance of 350 km. This suggests a certain independence of facies control. Tappan (1940, p. 95 and 1943, p. 481) gives the range of *Hap-*

lostiche texana (Conrad) in Texas from the higher Trinity (Lower Albian) to the Washita group (Upper Albian). The species is recorded abundantly only from the Del Rio clay, the Paw Paw sand, and the Weno clay, all of Upper Albian age. It is rare in deeper levels in the Gulf Coast. Its rate of abundance in Texas is further evidence for an Upper Albian age of the Colombian localities. In Venezuela *Haplostiche texana* (Conrad) is recorded from the Lower? to Middle Albian Placenta member of the Chimana formation (Rod and Maync 1954, p. 280) and from the Middle to Upper Albian Lisure formation (Rod and Maync 1954, p. 210). Considering the foraminiferal content and the lithology (high sand and glauconite content) of both the Venezuelan Lisure and the Colombian Tocuy a correlation of the two formations is obvious. Consequently the bulk of the Lisure formation is probably of Upper Albian age.

DESCRIPTIVE PALEONTOLOGY
Choffatella sogamosae (Karsten)

Plate 24, figures 1-3, text figures 5-7

Robulina sogamosae KARSTEN, 1856 (1858), Amtlicher Bericht 32. Versammlung deutscher Naturforscher und Aerzte in Wien, p. 114, pl. 6, figs. 5a, b.

Planulina xapatocensis KARSTEN, 1856 (1858), *ibid.*, p. 114, pl. 6, figs. 4a-d.

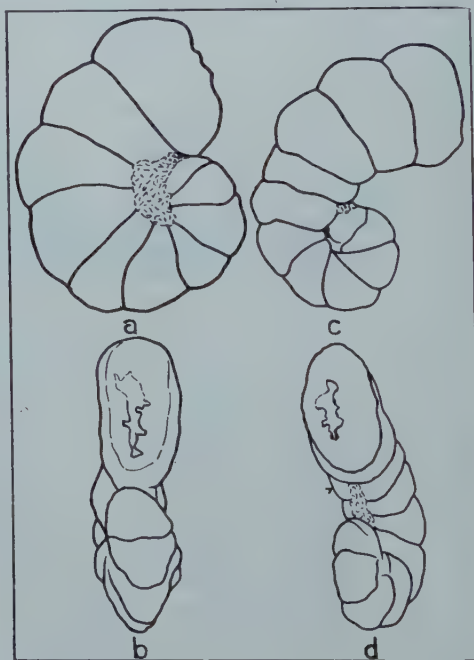
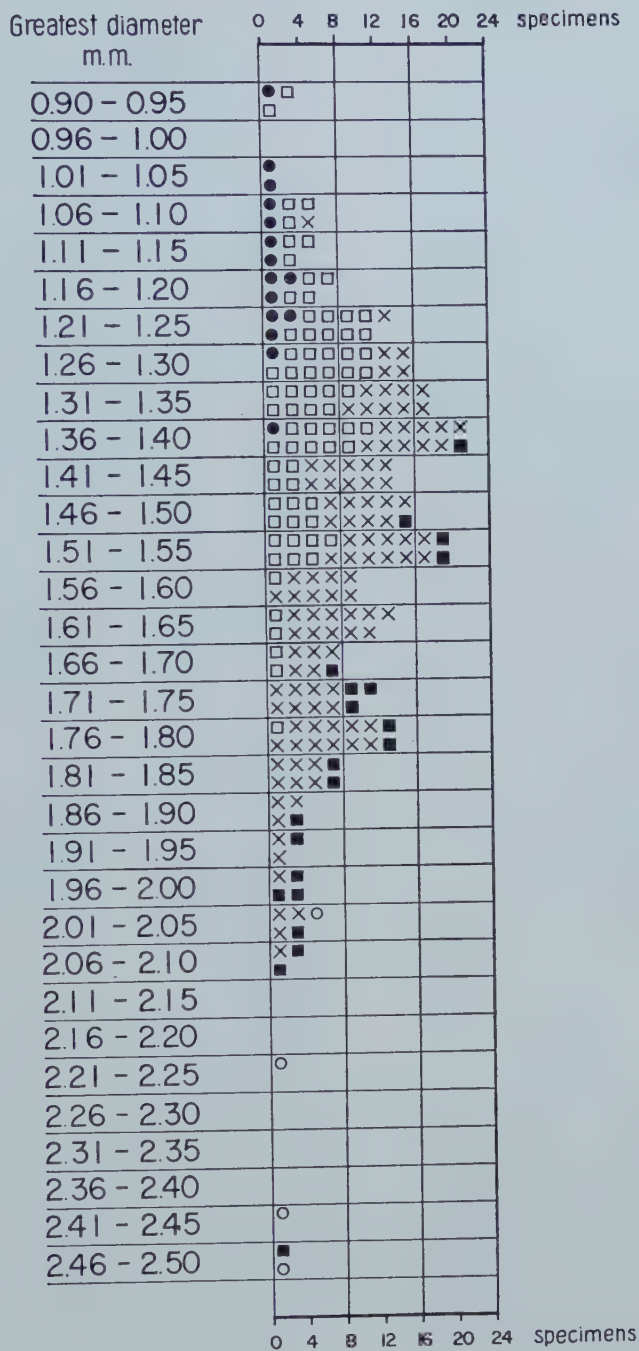


Fig. 6

Figs. 6a-d *Choffatella sogamosae* (Karsten), uncoiled specimens, locality No. 18, Upper Hauterivian, 14×.
a, c, side views
b, d, apertural views of same specimens



LEGEND

● 5 chambers	× 7 chambers	○ 9 chambers
□ 6 chambers	■ 8 chambers	

Fig.7 Variability of *Choffatella sogamosae* (Karsten)

Haplophragmoides sogamozae (Karsten), Dietrich, 1935, Zentralbl. Min. Geol. Pal., Abt. B, No 3, p. 78, figs. 9, 10.

The original spelling of Karsten's species name *sogamozae* is changed into *sogamosae*. The Sogamoso river where the type was found is spelled with *s* and not with *z*. Dietrich (1935, p. 78) considers *Robulina sogamozae* Karsten and *Planulina zapatocensis* Karsten as belonging to the same species. Own studies confirm this opinion, based on 250 specimens from the Mesa de Los Santos (locality No. 18¹) and on others from a few scattered localities.

Dietrich (1935, p. 78) stated that the forms are "without labyrinthic chamber structure" (translation from the German original). This holds true for the chamber lumina only. Thin sections (pl. 24, fig. 3) and even Dietrich's somewhat crude drawings Nos. 9 and 10 reveal a labyrinthic wall structure. Dietrich (1935, p. 78) mentions that the aperture "seems to be large, rounded and located at the inner side of the whorl" (translation from the German, italics by the writer). Karsten (1856, p. 114) states for *Planulina zapatocensis* that "the aperture is not preserved but irregularly incrustated" (translation from the German). His figure No. 4d shows a median elongate and somewhat crenulate depression. The general shape of this depression varies somewhat (text figures 5b, d, f, h) without, however, departing from the basic principle. Shale is filling most of the depression but sometimes a line of pores is seen at the bottom (text figure 5d). One or more larger openings are present on the older septa (pl. 24, fig. 3). They are similar to those described from *Pseudocyclammina virguliana* Koechlin (1943, pl. 6, fig. 2). They may have been formed by secondary resorption of the older chamber walls. A similar process is known from living calcareous foraminifera.

Dietrich's assignment of Karsten's species to the genus *Haplophragmoides* is considered erroneous, due to the structure of the chamber walls and of the aperture. The coarse labyrinthic chamber walls are suggestive of the genus *Pseudocyclammina*. The aperture, however, is not cribrate but resembles that of the genus *Choffatella*. *Buccicrenata* has a similar but slitlike aperture. Forms with a choffatelloid wall structure but having a pseudocyclamminoid aperture are generally placed with the genus *Pseudocyclammina* (*Ps. sequana*, *Ps. personata*) giving more weight to the characteristics of the aperture. The same principle was followed by the writer when assigning Karsten's species to the genus *Choffatella*.

The chambers of most tests are arranged in an involute, bilateral symmetric spiral, which becomes sometimes slightly asymmetrical, especially in large specimens (text figure 5j). The chambers of large

specimens do not completely join in the center but form a small open umbilicus (text figures 5e, g, i).

About 8 percent of the entire population develop a longer or shorter uncoiled portion. Tests with a longer uncoiled portion tend to have a small coiled stage (text figure 6c), those with only one or two chambers becoming loosely arranged show a large coiled stage (text figure 6a).

The last whorl of the entirely coiled tests consists of five to nine chambers. Five-chambered forms represent 7 percent of the total population, six-chambered 32 percent, seven-chambered 50 percent, eight-chambered 9 percent, and nine-chambered 2 percent. The greatest height of the tests varies between 0.90 and 2.50 mm (text figure 7). Most specimens fall between 1.36 and 1.55 mm, the number of the chambers increasing with the height of the tests (text figures 5a, c, e, g, i and 7). The frequency curves of each group formed by the specimens with the same number of chambers in the last whorl overlap, but the peak of the curves slopes more gradually from the smaller to the larger tests (text figure 7). The shape of the frequency curve of each group and that of the entire population suggests that only one species is present (text figure 7). Sections of many chambered specimens show fewer chambers in the inner whorls but the number of chambers is not considered as a function of the age of the individual.

The axial diameter of the tests is proportionally less increasing than the equatorial one (text figure 5b, d, f, h, j). The axial diameter amounts to an average of 50 percent of the equatorial one in five chambered specimens, to 46 percent in six and seven chambered, and to 40 percent in nine chambered specimens. Few specimens in each group are much narrower than the average (text figure 5h). They may represent microspheric forms.

The periphery of the tests is subacute. It resembles that of *Pseudocyclammina virguliana* Koechlin and *Ps. hedbergi* Maync.

Stratigraphic distribution.—Upper Hauterivian (to basal Barremian).

Epistomina mosquensis Uhlig

Plate 24, figures 4-7

Epistomina mosquensis UHLIG 1883, Jahrb. k. k. Geol. Reichsanst. Wien, Bd. 33, p. 766, pl. 7, figs. 1-3.

The Colombian specimens are identical with the Russian forms of Uhlig in the number of chambers, the double and partly spinose keel, and the biconvex test. Similar is also the variability in the ornamentation which shows generally a reticular pattern in the umbilical region of the ventral side (plate 24, fig. 5), but rarely also a simple ring (plate 24, fig. 7). A few of the Colombian specimens tend to become more plano-convex. The Colombian forms are never larger than 0.35 mm, whereas Uhlig's specimens "often reach

¹ The specimens were made available by H. Buergl from the Instituto Geológico Nacional de Colombia.

a diameter of 1 mm" (translation from the German original).

Stratigraphic distribution.—The Colombian specimens occur in the Barremian, Uhlig's forms from Russia in the Jurassic.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH

VOLUME V, PART 3, JULY, 1954

113. THE GENUS *NAVARELLA* CIRY AND RAT, 1951,
IN THE MAESTRICHTIAN OF SWITZERLAND

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ABSTRACT—A lituolid foraminifer, which was hitherto referred to as *Haplophragmium grande* (Reuss) and which occurs commonly in the late Cretaceous (chiefly Maestrichtian) Wang and Flysch deposits of Switzerland, is identified with *Navarella joaquinii* Ciry and Rat, 1951.

The original diagnosis of the genus *Navarella* is extended and the taxonomic relationship between the genera *Haplophragmium*, *Lituola*, and *Navarella* is discussed.

A new variety is distinguished which differs from *Navarella joaquinii* in the double-layered structure of its walls and septa.

It is suggested that *Lituola grandis* (Reuss) [= *Haplophragmium grande* (Reuss)], known to occur in many localities in the Alpine Region, will in many cases prove to be identical with *Navarella joaquinii* described from Spain, France, and Switzerland.

During 1953, Wolf Leupold, Professor of Micropaleontology at the Swiss Federal Institute of Technology of Zürich, showed me some interesting rock specimens from the south helvetic-ultrahelvetic Alps of central Switzerland. In connection with my recent studies on the Lituolidae he suggested a closer examination of a foraminifer commonly referred to as *Haplophragmium grande* (Reuss) by the Swiss geologists. This large-sized lituolid foraminifer occurs as a diagnostic fossil in great number in the so-called Wang beds and Maestrichtian Flysch series of Switzerland.

I am greatly indebted to Wolf Leupold for putting the material at my disposal. The present study is dedicated to him who taught me the principles of micropaleontology more than twenty years ago.

Furthermore, I am obliged to Raymond Ciry, Dijon (France), who kindly sent me some topotype material of *Navarella joaquinii* Ciry and Rat for a first-hand examination.

Hans H. Renz, Mene Grande Oil Company, Caracas, assisted in many ways. The given microphotographs were made by George Fournier to whom I render my special thanks.

The material examined from Leupold's collection (deposited in the micropaleontologic laboratory of the Swiss Federal Institute of Technology, Zürich) is as follows:

No. 42041. Glauconitic foraminiferal marly limestone (b)¹, 0.6 m above the conglomeratic base of the transgressive Wang beds (a)¹. Ultrahelvetic Bonvin (or Tothorn-Sex Mort) decke. Section Regenbolshorn, Adelboden, Canton of Bern.

No. 42005. Wang shale, 150 m southeast below the summit of Mittaghorn, Martinsmad (Elm), Canton of Glarus.

No. 36127. Platy marly Wang limestone, 50 m below the Lower Eocene unconformity. Southhelvetic Blattengrät series of Glarner Flysch. Trail from Badöni to Unter-Lavtina, Lavtina Valley (southern tributary of Weisstannen Valley), Canton of St. Gallen.

The topotype material of *Navarella joaquinii* Ciry and Rat, made available by Raymond Ciry, was collected south of the village of Ecay, Province of Navarra, northern Spain, in the uppermost portion of the late Cretaceous Flysch deposits.

The thin-sections and free specimens of *Navarella joaquinii* and of the new variety, *N. joaquinii* var. *helvetica* n. var., which are figured in the present study, are deposited in the micropaleontologic laboratory of the Swiss Federal Institute of Technology (ETH) in Zürich, Switzerland.

The large lituolid foraminifer, identified here as *Navarella joaquinii* Ciry and Rat, had been noticed by many geologists in the so-called Wang beds (Maestrichtian) of Switzerland.

Arnold Heim collected specimens in the glauconitic foraminiferal layer (b)² at the base of the Wang beds in the section of Regenbolshorn, Adelboden, Canton of Bern (Heim, 1920). H. Douvillé identified these large (up to 4 mm) globular foraminifera as *Lituola nautiloidea* Lamarck (ibid.). The same section was subsequently studied by Kurt Huber (Huber, 1933).

1 See section measured by Arnold Heim, 1920, Ecl. geol. Helv., vol. 15, pp. 473-477.

2 The material examined and partly figured here (sample No. 42041) is derived from the very same basal layer (b) of the Regenbolshorn section.

EXPLANATION OF PLATE 24

FIGS.		PAGE
1, 2.	<i>Choffatella sogamosae</i> (Karsten). 1 side view, 2 apertural view. Locality No. 19. Hauterivian. $\times 25$.	134
3.	<i>Choffatella sogamosae</i> (Karsten). Section. Locality No. 18. Hauterivian. $\times 25$.	134
4-7.	<i>Epistomina mosquensis</i> Uhlig. 4 dorsal view, 5 ventral view, 6 apertural view, 7 ventral view of other specimen. Locality No. 20. Barremian. $\times 150$.	136



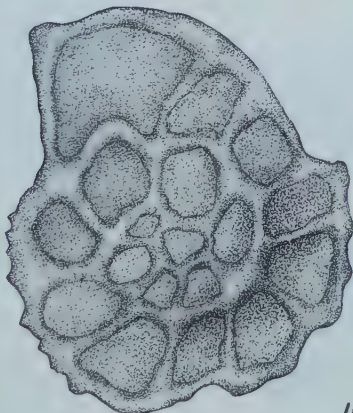
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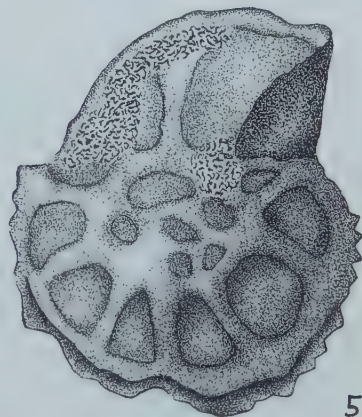
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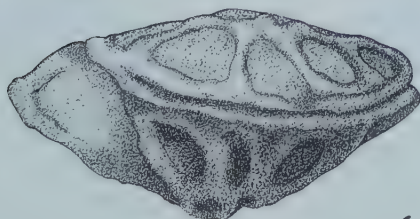
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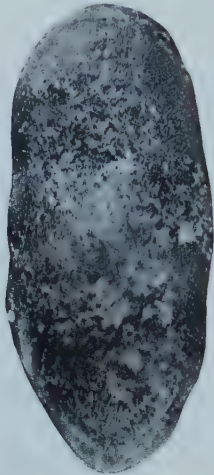


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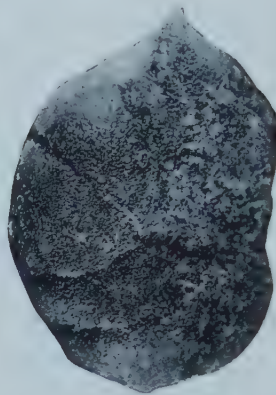
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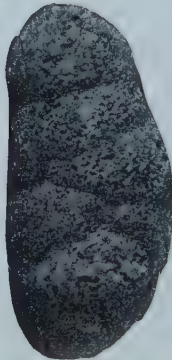
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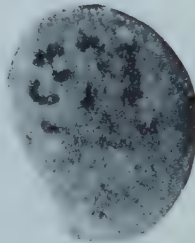
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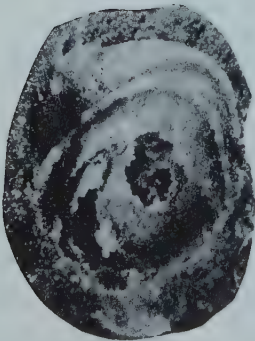
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Maync: *Navarella* in the Maestrichtian of Switzerland

Comparing these conspicuous lituolid foraminifera from the Wang beds of Regenbolshorn with *Lituola nautiloidea* Lamarck from Meudon, France, Huber and Leupold came to the conclusion that they were not identical; the specimens from the Swiss Wang beds were hence referred to as "*Lituolidae* (*Haplophragmoides*)" (Huber, 1933).

In his monograph on the Wang beds, Fritz Zimmermann refers the same foraminifer from Regenbolshorn to *Haplophragmium grande* (Reuss) which commonly occurs in the late Cretaceous Helvetic deposits ("Patenaumermergel," "Gerhardsreuterschichten," "Hachauerschichten") along the northern border of the Eastern Alps (Zimmermann, 1936)³.

Numerous specimens of this "*Haplophragmium grande*," associated with *Globotruncana stuarti* (Lapp.), were collected by Zimmermann on Klingenstock (area of Frohnalpstock, Canton of Schwyz).

Zimmermann's determination of the lituolid foraminifer from the Wang beds as "*Haplophragmium grande*" has since been generally accepted.

In 1935, Leupold succeeded in finding this "*Haplophragmium grande*" in the Wang beds of the type locality (Alp Wang, Canton of Schwyz).

The same foraminifer, stated to occur widely in the Wang beds of Switzerland, is recorded from the Maestrichtian Flysch series (Blattengrat complex) of the gorge of Badöni, Lavtina Valley, Canton of St. Gallen (Leupold, 1937). It is also listed from the Wang limestone (and locally from the underlying Amdener marls) (Bolli, 1944).

Dieter Staeger mentions *Haplophragmium grande* and *Globotruncana stuarti* (Lapp.) from the Wang limestone of the Wilerhorn, northeast of Brienz, Canton of Bern (Staeger, 1944).

³ It is very likely that a modern revision of the prolific material from the Eastern Alps (Bavaria, Austria) will reveal the identity of "*Haplophragmium grande*" (Reuss), pars, with *Navarella*.

"*Haplophragmium* and *Lituola*" are associated with *Globotruncana* of the *Stuarti* group in the Simmen Flysch (Maestrichtian) of the Gastlosen Range (Bieri, 1946).

The Sardona Flysch series (Canton of Glarus) also carries "*Haplophragmium grande*."

"*Haplophragmium grande*" was also found in the Gyrenspitz and Eggberg series of the pennine Prätigau Flysch (Campanian-Maestrichtian) of the Canton of the Grisons, accompanied by the diagnostic Maestrichtian form *Orbitoides media* (Arch.) and by *Siderolites heracleae* var. *pratigoviae* Arni, *Globotruncana stuarti* (Lapp.), *Gl. leupoldi* Bolli, and *Gl. lapparenti tricarinata* (Quer.) (Nänny, 1946).

It is beyond a doubt that this "*Haplophragmium grande*" (Reuss), which is widely recorded from the uppermost Cretaceous Wang and Flysch deposits of the south- and ultrahelvetic province of Switzerland, in most cases is identical with *Navarella joaquinii* Ciry and Rat.

There is every reason to assume that *Navarella* will be recorded in the future from a great many localities in the facies provinces where Wang or late Cretaceous Flysch beds were deposited. These *Navarella*-bearing levels will certainly be found in the south- and ultrahelvetic Alpine belt, from the Swiss region onwards into Liechtenstein, Vorarlberg, Bavaria, Austria, etc.

The genus *Navarella* was created in 1951, with *Navarella joaquinii* Ciry and Rat as genoholotype, for a *Lituola*-like foraminifer that abundantly occurs in the uppermost beds of the late Cretaceous of Navarra, northern Spain.

The original diagnosis is as follows (Ciry and Rat, 1951, pp. 76-81):

Test ovoid or pear-shaped, rather irregular, attaining a length of 4-5 mm, a breadth of 2.5-3 mm. Exter-

EXPLANATION OF PLATE 25

Figs.	PAGE
Figs. 1-4 <i>Navarella joaquinii</i> Ciry and Rat, 1951. Topotype material from south of Ecay, Navarra, Spain (uppermost level of late Cretaceous Flysch). Hypotypes.	
1. Isolated specimen with well-preserved uncoiled part (side view). $\times 12.5$	140
2. Same specimen as shown in Fig. 1, peripheral view. $\times 12.5$	140
3. Coiled portion of another specimen showing irregular chamber arrangement. $\times 10$	140
4. Same specimen as shown in Fig. 3, peripheral view. $\times 10$	140
Figs. 5-10 <i>Navarella joaquinii</i> Ciry and Rat, 1951. Wang beds (Maestrichtian), Regenbolshorn section (Adelboden), Ct. Bern, Switzerland (Sample No. 42041).	
5. Microspheric specimen (side view) exhibiting a well-defined coiled portion and a straight uncoiled adult part. $\times 10$	140
6. Megalospheric specimen (side view) showing the characteristic club-like tapering test with an irregular streptospiral coil. $\times 11.5$	140
7. View of cribrate aperture (thin-section). $\times 22$	140
Figs. 8-10. Etched specimens where part of the outer wall has been removed to show interior structure. All $\times 17.5$	
8. Completely embracing innermost chambers.	140
9. Strongly involute coil; simple spherical septa; bud-like structure.	140
10. Interior of a weathered specimen.	140
11. <i>Lituola taylorensis</i> Cushman and Waters. Side view of topotype Specimen (Taylor marl, Marques Dome, Leon Cty., Texas, U.S.A.) $\times 12$	143

nal ornamentation often lacking, yet sometimes gently depressed sutures visible which suggest the presence of internal septa. Three or four initial globular chambers in a close clew-like whorl (no consistent plane of coiling), followed by about 10 ovoid chambers which rapidly increase in size; at this stage, the spire forms a slightly irregular coil (not strictly planispiral); the chambers are strongly involute; the succeeding 3 or 4 loculi gradually become detached from the close spire but, rather than uncoiling along a rectilinear axis, they are arranged in a wide spire. This uncoiled portion of the test is usually short.

In the early coil, a slightly arched slit connects the lumina; at a later stage, a couple of circular small pores develop in addition to this juvenile slit-like foramen; in the adult uncoiling stage, the slit-like opening is lacking and the circular perforations which are distributed at random form the only interlocular communication.

Navarella is reported to have a two-layered wall, namely a homogeneous outer layer (0.1-0.18 mm thick) composed of small quartz grains held together by a calcareous cement, and an inner calcareous lining of a brownish color (attributed to the presence of ferruginous material). Such a calcareous-ferruginous interior layer is, however, consistently lacking in the numerous specimens at hand, and we strongly believe that this coating observed in the Spanish material is due to a mere secondary impregnation and should not be taken as an unambiguous attribute of the genus.

Additional post-mortem fillings of parts of the chambers with white calcite or with a dark-brown calcareous matrix are mentioned.

The original diagnosis of the monotypic genus *Navarella* was based on thin-sections and on observations made on polished surface sections of the *Navarella*-bearing rock specimens. Since quite a number of detached specimens could be washed out by the writer from some of the available samples, both from the type locality in Spain and from some Swiss samples, the description of the genus *Navarella* Ciry and Rat is herewith completed and in some respects emended.

Genus *Navarella* Ciry and Rat, 1951,
emend. Maync, 1954

In the material from the Wang beds of the Regenbolshorn section, two externally different forms are represented, namely a large stout one showing a well defined coiled portion and a small club-like form. The large *Lituola*-like type which was found to occur frequently is regarded as the *microspheric* form whereas the rarely encountered small specimens are interpreted as representing the *megalospheric* generation. Although both these types positively differ from each other in their external morphologic characteristics, they exhibit an identical interior structure.

Exterior appearance of test.

A) *Microspheric* generation. (Pl. 25, figs. 1-5)

Test stout, coiled portion large and nodulous with a broadly rounded periphery; adult specimens often with faint restrictions (septa); rectilinear or slightly forward curved uncoiled portion rarely present; typical cribrate aperture consisting of about a dozen elongate or vermicular openings which are distributed over the greater part of the apertural face (Pl. 25, fig. 7).

Diameter of coiled portion: 2.0-4.0 mm.

Total length of adult test: 4.5-5.5 mm.

Thickness (short axis): 1.4-2.5 mm.

B) *Megalospheric* generation. Pl. 25, fig. 6)

Test elongate-cylindrical, club-like, broadly rounded, relatively small; externally no sharply defined coiled portion visible, usually gradually tapering into the uncoiled part; chambers and sutures as a rule very indistinct; irregular constrictions sometimes discernible which reflect the streptospiral mode of coiling; multiple aperture.

Total length of adult test: 3.0-4.2 mm.

Greatest breadth: 1.5-2.0 mm.

Interior structure

Plate 25, figures 8-10

Plate 26, figures 1-9

Plate 27, figures 1-6

A large number of weather-worn specimens of *Navarella* from the Regenbolshorn section could be broken loose from the matrix and were further opened by means of needle and weak acid. In this way, valuable data on the inner structure could be obtained.

Three or four initial globular chambers in a tight coil are followed by 6-9 narrow chambers which rapidly increase in size and overlap one another like leaves in a bud; the spire is usually irregular (coiled in shifting planes); it is wholly involute and one convolution embraces the preceding one; the spherically enveloping septa are pronouncedly curved backwards; the succeeding 3 or 4 chambers gradually became detached from the close coil (consisting of 2-4 spiral convolutions) and uncoil either straight or sometimes in a very loose spire like many species of *Lituola*; 2 or 3 conically shaped chambers effect the transition of the spire into the detached adult portion.

In the early coil, a slightly arched slit is reported to connect the lumina (Ciry and Rat, 1951, p. 77); at a later stage, a couple of circular small pores develop in addition to this slit-like opening, and in the adult uncoiling stage the slit-like foramen is missing altogether and the perforations form the only interlocular communication (see Pl. 26, figs. 8-9). The terminal aperture is truly cribrate (see Pl. 25, fig. 7).

The broken up specimens of *Navarella Joaquina* from Regenbolshorn, reveal that both walls and the

sickle-shaped, onion-layered septa are composed of a thin layer of fine sugary quartz grains held together by a small amount of a calcareous cement. As pointed out by Ciry and Rat, the closely packed quartz grains are arranged in such a way that one of their plane surfaces is oriented towards the outside of septa and walls, while the intergrowth of the quartz grains below this septal facets is more irregular.

None of the numerous individuals examined showed any traces of an inner calcareous layer such as is reported by Ciry and Rat. It is neither observed in the available type material, nor do the prepared thin-sections exhibit this kind of a two-layered wall structure. The writer thinks that the ferruginous-calcareous inner coating observed by Ciry and Rat must be a secondary phenomenon (subsequent impregnation of the interior of the tests).

On the other hand, some of the Swiss specimens of *Navarella joaquinii* may develop an outer layer of variable thickness which obviously serves as a reinforcement of the large-sized adult test. This layer consists of an aggregate of mainly calcitic radiate fibres (arranged perpendicularly to the walls and septa). In all the studied samples from Lavtina Valley (No. 36127), this white fibrous covering layer is consistently developed, already within the spiral portion of the test (Pl. 27, figs. 7-10), and may attain a thickness of 0.5 mm. On account of this difference in the wall structure, the writer prefers to regard the last-mentioned specimens showing the reinforcing additional outer layer as a new variety of *Navarella joaquinii* Ciry and Rat for which the name *Navarella joaquinii* var. *helvetica* n. var. is herewith proposed.

Navarella joaquinii Ciry and Rat var.
helvetica Maync, n. var.

Plate 27, figures 7-10

The variety *helvetica* differs from the species *Navarella joaquinii* Ciry and Rat, 1951, in showing a consistent second reinforcing layer of fibrous calcite on top of the finely arenaceous walls and septa.

Such an outer layer may occasionally develop in *N. joaquinii* (see Pl. 27, figs. 2-4) but is not a constant morphologic feature. In the variety *helvetica*, however, this white exterior layer is never absent and even covers walls and septa within the young spiral portion of the test. Scattered quartz grains within the calcitic outer layer were observed in some specimens of the variety *helvetica* (absorption), and even a partial replacement of the arenaceous layer was locally noticed. In many cases, the outer fibrous layer may reach several times the thickness of the arenaceous one. As a rule, the arenaceous layer is considerably coarser in the variety *helvetica* (larger quartz grains).

Consequently, both walls and septa are much thicker in the new variety but otherwise the interior structure

(mode of coiling, strongly arched septa, embracing chambers, etc.) appears to be identical.

The lumina of *N. joaquinii* var. *helvetica* are partially filled with a dark-brown pigmented material which is assumed to be a post-mortem infiltration. It is conceivable that a similar impregnation of the chambers has led Ciry and Rat to the idea of a double-layered wall structure (arenaceous layer with an inner ferruginous-calcareous coating).

Only microspheric specimens of this new variety are represented in the available material.

Dimensions:

Greatest diameter (breadth) of coiled portion: 2.5-3.0 mm. (A single specimen measures 5.0 mm).

Total length: 3.5-6.0 mm.

(One specimen weathered out on the rock surface shows a coiled portion of 2 mm in breadth which is succeeded by an extremely long uncoiled stage (6 chambers) attaining a length of 8.2 mm.

The examined specimens of *Navarella joaquinii* var. *helvetica* generally attain a considerably greater length than *N. joaquinii*. This fact may be in connection with the thicker and reinforced walls of the new variety allowing its test to stand mechanical damage.

Type locality of *Navarella joaquinii* var. *helvetica*: Sample No. 36127, on trail from Badöni to Unter-Lavtina, Lavtina Valley, Canton of St. Gallen, Switzerland (Wang limestone in Blattengrät series of Glarner Flysch).

TAXONOMY

The mere fact that *Navarella* was repeatedly identified as "*Haplophragmium grande*" (Reuss) indicates strong affinities between the two forms.

With respect to its external features, the microspheric form of *Navarella* very closely agrees with *Haplophragmium grande* (Reuss) which is a widely distributed species of the Upper Campanian and Maestrichtian of Bavaria, Austria, etc. (Reuss, 1854, Pl. XXV, figs. 14 a-b; Bartenstein, 1952, Pl. 4, figs. 8-13). The regularly coiled forms of *Lituola westfalica westfalica* Bartenstein, 1952, also bear a certain resemblance to the microspheric forms of *Navarella* (Bartenstein, 1952, Pl. 5, fig. 4).

The megalospheric generation of *Navarella* externally rather resembles certain irregularly coiled forms, such as *Haplophragmium aequale* (Roemer) sp. (Reuss, 1862, Pl. I, figs. 4-7), which are, however, endowed with a simple aperture (*Navarella joaquinii* has a multiple aperture in form of several closely spaced irregular openings). Another form which is externally similar to *Navarella joaquinii* (megalospheric generation) is *Haplophragmium aequale* Franke (non Roemer) (Franke, 1928, Pl. XV, fig. 15).

J. Hofker is inclined to believe that *Haplophragmium aequale* (Reuss) Hofker from the Maestrichtian might be the microspheric form of *Haplophragmium grande* (Hofker, 1949).

There also exist some external similarities between *Navarella joaquinii* (megalospheric form), *Haplophragmium bullatum* Perner, 1897, and *Haplophragmium* (?) *asperum* Perner, 1897, from the Turonian of Bohemia, Czechoslovakia. Our knowledge concerning these foraminifera and their interior structure is, unfortunately, too limited to allow a taxonomic comparison. Both the Bohemian forms, however, are stated to possess a simple aperture.

To some extent, the taxonomy of the *Lituolidae* is still problematical. A revised classification was recently attempted by the writer (Maync, 1952) but some questions have remained unanswered. It has become evident that the genus *Haplophragmium* Reuss, 1860, actually embraces very heterogenous forms which cannot be accommodated in one single genus. The forms showing a planispiral initial coiling and a simple aperture were separated from *Haplophragmium* and included in the genus *Ammobaculites* (Cushman, 1910). Those displaying a regular early spire and a multiple (cribrate) aperture were placed in synonymy with *Lituola* Lamarck, 1804 (Marie, 1941; Maync, 1952; Bartenstein, 1952). The remaining forms, i.e. those exhibiting a streptospiral early coiling and a simple or multiple aperture, were retained in the "catch-all" genus *Haplophragmium*.

According to the original definition by A. E. Reuss (1860), *Haplophragmium* is the arenaceous pendant to the calcareous *Spirolina* Lamarck, 1804 (non Roemer!). Both genera possess a planispiral initial coil. The subsequently designated lecto-genotype of *Haplophragmium*, *Spirolina aequalis* Roemer, 1841, from the Lower Cretaceous, however, displays an irregularly twisted early coil, and, moreover, a simple apertural opening. Consequently, there is some ambiguity between Reuss' concept of his genus and the later selected genotype.

The genus *Haplophragmium* was also interpreted to include Upper Cretaceous tests which — on account of their interior structure and multiple aperture — are

positively referable to *Lituola* Lamarck. Bartenstein retains the generic name *Haplophragmium* (pars) for those Lower Cretaceous forms that show the characteristics of *Spirolina aequalis* Roemer, 1841 (planispiral or streptospiral early coil, uncoiled portion, simple aperture). A differentiation between these representatives of *Haplophragmium* and *Ammobaculites* is seen in a slightly different wall structure ("pseudo-labyrinthic," i. e., irregularly contoured lumina, in *Haplophragmium*; evenly outlined chambers in *Ammobaculites*) (Bartenstein, 1952).

Considering the mode of coiling as a basic taxonomic criterion, the writer proposed two new genera, namely *Bulbophragmium* for the streptospirally coiled representatives of the *Lituola* lineage (with multiple apertures), and *Bulbobaclulites* for the streptospirally coiled forms of the *Ammobaculites* group (with a simple aperture) (Maync, 1952). Bartenstein, on the other hand, believes that the mode of the early coil is insignificant for a generic differentiation, and considers the streptospirally coiled forms to represent the megaspheric generation, whereas the planispiral tests are suggested to be the microspheric form of the same genus (Bartenstein, 1952).

It seems that this concept might, indeed, hold true, at least if the two different tests observed in the *Navarella* assemblages actually represent the same genus (micro- and megaspheric forms). If Bartenstein's view should prove to be correct, the genera *Bulbophragmium* Maync, 1952, for streptospirally coiled forms of *Lituola*, and *Bulbobaclulites* Maync, 1952, for the irregularly twisted representatives of *Ammobaculites*, would only indicate different generations. Only large populations should, however, be examined before a conclusive answer on this problem can be offered.

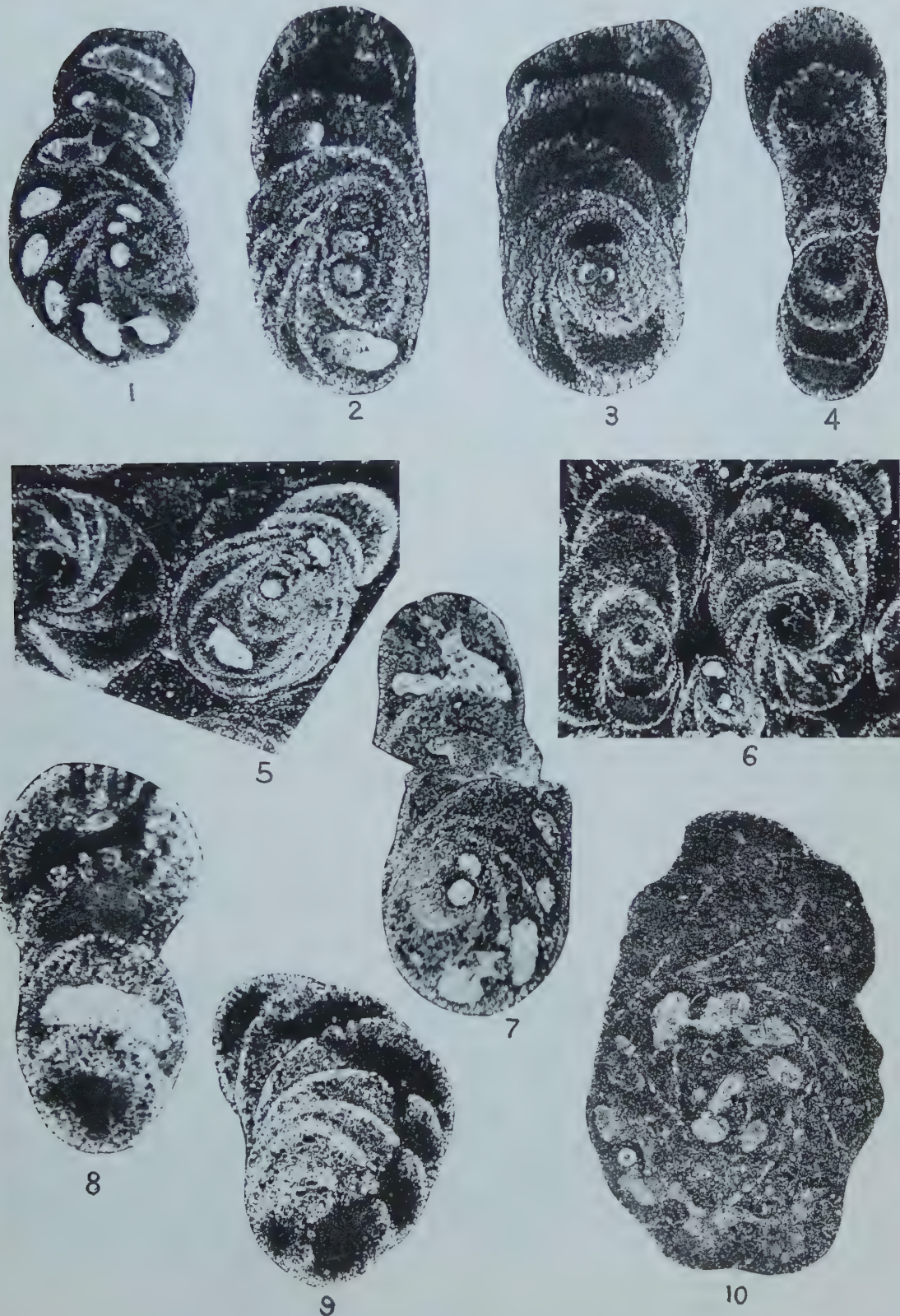
In spite of the still problematic taxonomic position of the *Haplophragmium* forms displaying a simple aperture (group *Ammobaculites-Bulbobaclulites*, Maync, 1952; *Haplophragmium* (pars), Bartenstein, 1952), a

EXPLANATION OF PLATE 26

Figs.

PAGE

- | | | |
|---|--|-----|
| Figs. 1-9 <i>Navarella joaquinii</i> Ciry and Rat, 1951. Thin-sectioned topotype specimens from south of Eca, Navarra, Spain. | | |
| 1. | Approximately equatorial section showing coiled portion and subsequent rectilinear part; chambers partially filled with calcite (white). $\times 12$ | 140 |
| 2. | Approximately equatorial section through initial spire; spherical septa; bud-like structure; uncoiled portion. $\times 15$ | 140 |
| 3. | Equatorial (median) section through another microspheric specimen. $\times 12$ | 140 |
| 4. | Axial section. $\times 12$ | 140 |
| 5. | Random section. $\times 10$ | 140 |
| 6. | Random section. $\times 10$ | 140 |
| 7. | Approximately median section showing spire and (secondarily displaced) uncoiled portion; multiple aperture. $\times 12$ | 140 |
| 8. | Subaxial section with clearly visible cribrate aperture. $\times 12$ | 140 |
| 9. | Tangential section showing the interocular communication by a single foramen in the early stage, by multiple openings in the adult portion of the spire. $\times 14$ | 140 |
| 10. | <i>Lituola taylorensis</i> Cushman and Waters. Median section of topotype specimen (Taylor marl, Marquez Dome, Leon Cty., Texas, U.S.A.). $\times 27$ | 143 |



Maync: *Navarella* in the Maestrichtian of Switzerland



Maync: *Navarella* in the Maestrichtian of Switzerland

form like *Haplophragmium grande* (Reuss) with its simple internal structure and cribrate aperture has to be allocated to the genus *Lituola* Lamarck and should hence be listed as *Lituola grandis* (Reuss).

A critical morphological comparison reveals that the genera *Lituola* and *Navarella* do not differ in their principal features. Both include simple arenaceous tests which show an initial spire, a more or less pronounced uncoiled stage, and multiple apertures. *Navarella* differs from *Lituola* in its clew-like initial spire and irregular mode of coiling through all stages (successive planes of coiling often describing a sigmoid flexure); the megalospheric form is characterized by an irregular streptospiral early coil, such as is typical of the initial spire in *Bulbophragmium*.

From both *Lituola* and *Bulbophragmium*, *Navarella* is distinguished by its well-developed spherical septa (bud-like arrangement) and its wholly involute spire in which the coils completely cover the earlier chambers.

Future studies of *Lituola* and its close allies might show that forms like *Navarella* should rather be placed in *Lituola* and possibly be given subgeneric status. No topotype material of the very similar Upper Cretaceous species of *Lituola* (*L. grandis*, *L. irregularis*, etc.) is, unfortunately, available to the author, which is absolutely necessary in order to draw any final conclusions in this respect.

Navarella was compared by its authors to some apparently related forms of the Lituolidae. It differs from *Lituola difformis* Lamarck⁴ in showing a streptospiral coil instead of a large planispiral one with involute chambers. In *Lituola difformis* Lamarck, the interocular communication is only affected by circular perforations whereas a slit-like opening is present in early stages of *Navarella*. *Lituola taylorensis* Cushman and Waters⁵ is stated by Ciry and Rat to have a strictly

rectilinear uncoiled portion (sometimes even bent away from the direction of coiling⁶ and distinct sutures⁷). Thin-sections reveal, moreover, a regular spire wound up in one single plane, with thin strongly curved septa similar to those in *Navarella* (Maync, 1952, Pl. 11, figs. 1-2).

Stratigraphic distribution
and occurrence of *Navarella*

Navarella, with *Navarella joaquinii* as genoholotype, was first described from the uppermost Cretaceous Flysch beds (a few meters below the contact with the overlying *Nummulites*-bearing limestone), exposed near the villages Ecay and Errez, in the northwestern Province of Navarra, northern Spain.

The prolific occurrence of *Navarella* in the Maestrichtian Wang beds and in the late Cretaceous Flysch series of Switzerland is stressed in the present paper.

Typical specimens of *Navarella joaquinii* were, moreover, figured by J. Cu villier and V. Sacal as "grands Foraminifères arénacés (Lituolidés)" (Cu villier and Sacal, 1951, Pl. LXI, fig. 1). This *Navarella*-bearing rock was collected in the "Danian" (Flysch facies) of Angoumé (Landes), southwestern France. A single specimen of *Navarella* (or of a very close ally), figured by these authors (ibid., Pl. LV, at extreme right of Fig. 2), is derived from Flysch beds of Maestrichtian age southwest of Orthez, Oraas (Basses Pyrenées, southern France).

These occurrences show that *Navarella* is a very characteristic microfossil of the Wang beds and the Flysch series of Campanian to Maestrichtian age in the domain of the Alpine orogenesis. It is recorded from the Pyrenees, from the south- to ultrahelvetic Swiss Alps, and occurs most likely in the Eastern Alps of Bavaria and Austria ("*Haplophragmium grande*")

6 This criterion is not borne out by the topotype material at hand.

7 In the available topotype specimens the sutures are often marked as real restrictions which cause the lobulate outline of most tests.

EXPLANATION OF PLATE 27

FIGS.	PAGE
Figs. 1-6 <i>Navarella joaquinii</i> Ciry and Rat, 1951. Wang beds (Maestrichtian) section Regenbolshorn (Adelboden), Ct. Bern, Switzerland (Sample No. 42041). 1-5 Microspheric tests.	
1. Sub-equatorial section showing involute spire. × 18	140
2. Approximately median section. Trace of additional outer wall layer of fibrous calcite (terminal area). × 14	140
3. Axial section disclosing slight septal depressions (interluminar perforations); additional calcite layer (white) at periphery. × 21	140
4. Median section. Distinct additional layer of fibrous calcite (white) visible at the base. × 19	140
5. Megalospheric generation. Interior structure as seen on a polished surface section; clew-like spire and straight uncoiled portion. × 13	140
6. Median section of megalospheric specimen (thin-section). × 15	140
Figs. 7-10 <i>Navarella joaquinii</i> Ciry and Rat var. <i>helvetica</i> Maync, n. var. Wang limestone (Maestrichtian) in Blattengrat series of Glarner Flysch. Lavtina Valley, Ct. St. Gallen, Switzerland (Sample No. 36127).	
7. Holotype. Median section showing internal structure of <i>Navarella joaquinii</i> and the modified character of walls and septa (consistently developed additional layer of fibrous calcite). × 10	141
8. Median section through a specimen displaying an extremely well-developed uncoiled portion. × 12	141
9. Median section of a specimen exhibiting a very thick wall. × 11.5	141
10. Equatorial sections. × 9.5	141

(Reuss)). *Navarella joaquinii* Ciry and Rat and its new variety *helvetica* are found abundantly in sandy glauconitic sediments of latest Cretaceous age and may definitely be regarded as diagnostic markers of these orogenic deposits.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME V, PART 3, JULY, 1954

RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the Foraminifera that have come to hand.

- AKERS, W. H. Ecologic aspects and stratigraphic significance of the foraminifer *Cyclammina cancellata* Brady.—Journ. Pal., vol. 28, No. 2, March 1954, pp. 132-152, text figs. 1-10.—Worldwide distribution in cool waters below continental shelf depths.
- ALBRITTON, CLAUDE C. JR., SCHELL, WILLIAM W., HILL, CHARLES S., and PURYEAR, JOHN R. Foraminiferal populations in the Grayson marl.—Bull. Geol. Soc. Amer., vol. 65, No. 4, April 1954, pp. 327-336, text figs. 1-3.—Interpretation of ecologic conditions based on quantitative study of families and genera from the four lithologic units of the Grayson.
- ASANO, K. Miocene Foraminifera from the Noto Peninsula, Ishikawa Prefecture.—Short Papers from the Institute of Geology and Paleontology, Tohoku Univ., Sendai, No. 5, Dec. 15, 1953, pp. 1-21, pls. 1-3, tables 1, 2.—The fauna (about 200 species) is listed and 15 new species and subspecies described and illustrated.
- Oligocene Foraminifera from Utsunai, Tonbetsu-mura, North Hokkaido.—Short Papers from the Institute of Geology and Paleontology, Tohoku Univ., Sendai, No. 5, Dec. 15, 1953, pp. 22-24, 1 pl.—Five species are illustrated, none new.
- BARNARD, TOM, and BANNER, FREDERICK T. Arenaceous Foraminifera from the Upper Cretaceous of England.—Quart. Journ. Geol. Soc. London, vol. 109, pt. 2, Dec. 11, 1953, pp. 173-212, pls. 7-9, text figs. 1-8.—Forty species and varieties (7 new and one indeterminate) were studied, particularly as to internal structure. Five families are represented. A range chart shows the ranges of certain species.
- BARTENSTEIN, HELMUT. Nachweis der zwischen 1948 und 1952 aufgestellten Foraminiferen-Gattungen nach Familien geordnet.—Paläont. Z., Band 27, No. 3/4, August 1953, pp. 220-232.
- BYKOVA, E. V. Foraminifery Devona Russkoi Platformy Priuralia.—Mikrofauna SSSR, Sbornik V, 1952, pp. 5-64, pls. 1-14.—Thirty-five species (all but 2 new) are recorded and illustrated. They are included in 13 genera, the following new: *Uralinella* n. gen. (genotype *U. bicamerata* n. sp.) in Astorhizidae; *Evlania* n. gen. (genotype *E. transversa* n. sp.) in Ophthalimididae?; *Fronidilina* n. gen. (genotype *F. devexis* n. sp.), *Multiseptida* n. gen. (genotype *M. corallina* n. sp.), and *Tikhinella* n. gen. (genotype *T. measpis* n. sp.) in Lagenidae; *Cremsia* n. gen. (genotype *Textularia*? *proboscidea* Cushman and Stainbrook) in Heterohellicidae?.
- LeCALVEZ, YOLANDE, and FEUGUEUR, LÉON. Les Foraminifères du "Niveau d'Hérrouval" à Hérrouval (Oise).—Bull. Soc. Géol. France, 6th ser., vol. 3, fasc. 4-6, 1953, pp. 503-508, pl. 1.—Forty-seven species are listed, of which 2 are described and figured as new, from these beds assigned to the Cuisian.
- CHANG, LI-SHO. New occurrence of smaller Foraminifera in the Nanchuang Coalfield and their stratigraphic significance in Taiwan.—The Formosan Mining Industry, vol. 5, No. 1, April 1953, 3 pp., table 1.—A few species are listed from Miocene beds.
- The lower Oligocene Yuhangian foraminiferal faunule and its stratigraphic significance in Taiwan.—Bull. Geol. Survey Taiwan, No. 5, Jan. 1954, pp. 101-116, pls. 1-4, text fig. 1 (map), tables 1, 2.—Forty-two species and varieties, one new, are recorded and illustrated.
- CHEYLAN, GILBERT, MAGNÉ, JEAN, SIGAL, JACQUES, and GREKOFF, NICOLAS. Résultats géologiques et micropaléontologiques du sondage d'El Krachem (Hauts Plateaux Algérois). Description de quelques espèces nouvelles.—Bull. Soc. Géol. France, 6th ser., vol. 3, fasc. 4-6, 1953, pp. 471-492, pl. 14, text fig. 1, tables 1, 2.—Nine new species, 4 from the Miocene and 5 from the Upper Cretaceous, are described and figured. The complete faunas, 38 Foraminifera from the Miocene and 35 from the Cretaceous, are plotted on two tables.
- CONSONNI, E. Studi stratigrafici sul Terziario Subalpino Lombardo. Nota II, La formazione gonfolitica della Brianza tra Romanò e Naresso.—Riv. Ital. Pal. Stratig., vol. 59, No. 4, 1953, pp. 173-194, pl. 12.—Twenty-two species are listed (8 of them illustrated) and notes included on their age significance.
- CUVILLIER, JEAN, and DEBOURLE, ANDRÉ. Découverte du Jurassique terminal et du Néocomien en Aquitaine occidentale et méridionale.—C. R. S. Soc. Géol. France, No. 4, Febr. 15, 1954, pp. 75, 76.—Foraminifera are mentioned.
- GIANOTTI, A. Rettifica di nomenclatura di Foraminiferi per omonimia.—Riv. Ital. Pal. Stratig., vol. 59, No. 4, 1953, p. 206.—*Bolivina fastigia* var. *dertonensis*, n. name for var. *miocenica* Gianotti (not Macfadyen, 1930).
- HAGN, HERBERT. Über einen alluvialen Foraminiferenmergel von Neubauern am Inn, Ein Beitrag zur Kenntnis von Umlagerungsvorgängen.—Abh. Neues Jahrb. Geol. Pal., Band 89, heft 3, Febr. 1954, pp. 395-446, pls. 26-28, text figs. 1, 2, tables 1, 2.—Foraminifera are listed from the Cretaceous and Eocene and a few Eocene ones are illustrated.
- HAGN, HERBERT, and HOLZL, OTTO. Zur Grenzziehung Katt/Aquitain in der bayerischen Molasse.—Mitth. Neues Jahrb. Geol. Pal., Febr. 1954, pp. 1-40, tables 1, 2.—Numerous Foraminifera are mentioned.
- HORNIBROOK, N. de B. Jurassic Foraminifera from New Zealand.—Trans. Royal Soc. New Zealand, vol. 81, pt. 3, Dec. 1953, pp. 375-378, text figs. I, II.—Four species, one (*Lingulina evansi*) new.
- KANMERA, KAMETOSHI. The Lower Carboniferous Kakisako formation of southern Kyushu, with a description of some corals and fusulinids.—Mem. Fac. Sci. Kyushu Univ., ser. D, Geol., vol. 3, No. 4, 1952, pp. 157-177, pls. 8-12, text figs. 1, 2.—Four species of *Millerella*, two new.

- KEYZER, F. G. Reconsideration of the so-called Oligocene fauna in the asphaltic deposits of Buton (Malay Archipelago). 2. Young-Neogene Foraminifera and calcareous algae.—*Leidse Geol. Mededelingen*, deel 17, 1953, pp. 259-293, pls. 1-4, table 1.—About 325 species and varieties are listed, with abundance indicated. The age is re-determined as Miopliocene. Two new genera: *Amphimorphinella* (genotype *A. butonensis* n. sp.) and *Ruttenella* (genotype *R. butonensis* n. sp.) are erected. Twenty-three new species and 4 new varieties are described and illustrated.
- MALECKI, J. *Flabellaminopsis*, new genus of agglutinated Foraminifera from the Dogger in the vicinity of Czestochowa.—*Ann. Soc. Geol. Pologne*, vol. 22, fasc. 2, Ann. 1952, Jan. 15, 1954, pp. 101-122, pls. 3-5, text figs. 1-3.—*Flabellaminopsis* (genoholotype *F. variabilis* n. sp.) and 9 new species.
- NEUMANN, MADELEINE. Sur un *Cibicides* nouveau du Lutétien supérieur d'Aquitaine: *Cibicides daguerri* n. sp.—*C. R. S. Soc. Géol. France*, No. 5, March 1, 1954, pp. 113, 114, text figs. A-C.
- NEUMANN, MADELEINE, and BOULANGER, DOMINIQUE. *Discorbis* (*Lamellosdiscorbis*) *magna* Vialli, var. *aquitania* nov. var., Foraminifère caractéristique des marnes à *Xanthopsis dufouri* de la Chalosse (Landes).—*C. R. S. Soc. Géol. France*, No. 5, March 1, 1954, pp. 114-117, text figs. 1, 2.—From beds attributed to lower Lutetian.
- NICOSIA, MARIA LUISA. Foraminiferi Oligocenici delle "Argille Rosse" di Catenanuova (F^o 269 "Paternò"-Sicilia).—*Boll. Serv. Geol. d'Italia*, vol. 74, Anno 1952, fasc. 2, 1953, pp. 391-405, pls. 1-3.—Twenty-eight species, none new, are recorded and most of them illustrated.
- PAPP, A., and KÜPPER, K. Die Foraminiferenfauna von Guttaring und Klein St. Paul (Kärnten). I. Über Globotruncanen südlich Pernerger bei Klein St. Paul.—*Osterreich. Akad. Wissenschaften, Sitz., Abt. I*, Band 162, heft 1, 2, 1953, pp. 31-48, pls. 1, 2.—Three species and three subspecies (one new) of *Globotruncana*, as well as two other species, are described and figured. New generic assignments are made for several species mentioned by Liebus from this locality.
- Die Foraminiferenfauna von Guttaring und Klein St. Paul (Kärnten). II. Orbitoiden aus Sandsteinen vom Pernerger bei Klein St. Paul.—*Osterreich. Akad. Wissenschaften, Sitz., Abt. I*, Band 162, heft 1, 2, 1953, pp. 65-82, pls. 1-4.—Three species (one new) and two subspecies (one new) are described and figured.
- PHLEGER, FRED B. Ecology of Foraminifera and associated micro-organisms from Mississippi Sound and environs.—*Bull. Amer. Assoc. Petr. Geol.*, vol. 38, No. 4, April 1954, pp. 584-647, pls. 1-3, text figs. 1-28 (maps), tables 1-11.—A quantitative study in which four facies, as well as subdivisions of facies and mixing of faunas, are recognized. Problems of geological application of faunal analyses are discussed. About 60 species and varieties are recorded and illustrated.
- PURI, HARBANS SINGH. Check list of Indian Tertiary larger Foraminifera.—*Journ. Pal.*, vol. 28, No. 2, March 1954, pp. 185-194.
- RIVEROLL, D. D., and JONES, B. C. Varves and Foraminifera of a portion of the upper Puente formation (upper Miocene), Puente, California.—*Journ. Pal.*, vol. 28, No. 2, March 1954, pp. 121-131, text figs. 1-8.—Thirty-three species of Foraminifera, not all identifiable, are recognized in the "crushed foram" layers of the varves. These layers, brown and rich in organic content, are interpreted as the summer layers. Winter layers are grey and barren of Foraminifera. This type of deposition and the significance of rhythmic occurrence of certain foraminiferal assemblages are discussed.
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- SCHROEDER, MELVIN C., and BISHOP, ERNEST W. Notes on Foraminifera from the Late Cenozoic in southern Florida.—*Journ. Pal.*, vol. 28, No. 2, March 1954, pp. 210-213, text fig. 1 (map), tables 1, 2.—A few of the numerous species present are useful in differentiating formations.
- SHUTO, TSUGIO. A study on the foraminiferal assemblage of Omura Bay, Nagasaki Prefecture, Kyushu.—*Japan Journ. Geol. Geogr.*, Trans. vol. 23, March 30, 1953, pp. 127-138, text figs. 1-8, tables 1-3.—A quantitative study of an enclosed embayment. Genus and family compositions in various parts of the bay are shown on maps and a graph. Distribution and quantity studied of about 245 species are shown in a table. Two new species are described and illustrated.
- TACOLI, M. L., and MANTOVANI, M. P. Foraminiferi delle "marne turchine" del Rio Corlo.—*Atti Soc. Toscana Sci. Nat.*, Mem. vol. 59, ser. A, 1952, pp. 128-177, pls. 1-3, table.—Ninety-three species, none new, are recorded and most of them illustrated, from beds referred to Piacenzian.
- TAKAYANAGI, Y. New genus and species of Foraminifera found in the Tonohama group, Kochi Prefecture, Shikoku.—*Short Papers from the Institute of Geology and Paleontology, Tohoku Univ.*, Sendai, No. 5, Dec. 15, 1953, pp. 25-36, pl. 4.—Fourteen new species, in 13 genera, are described and illustrated from the Pliocene of Japan. One new genus, *Tosaia* (genotype *T. hanzawai* n. sp.), is erected in the family Heterohellicidae.
- TODD, RUTH. The smaller Foraminifera in correlation and paleoecology.—*Science*, vol. 119, No. 3092, April 2, 1954, p. 448.
- TORIYAMA, RYUZO. Permian fusulinids from the Kitakami mountainland, northeast Japan.—*Mem. Fac. Sci., Kyushu Univ.*, ser. D, vol. 3, No. 3, 1952, pp. 127-156, pls. 3-7, 1 table.—Twenty-three species and varieties, mostly indeterminate, are described and illustrated.
- TORRENTE, ANTONIO. Contributo alla Conoscenza della stratigrafia del Calabrian e del Pliocene Superiore e Medio della Pianura Pontina.—*Boll. Serv. Geol. d'Italia*, vol. 74, Anno 1952, fasc. 2, 1953, pp. 419-429, distribution table.—Distribution and abundance of 95 species from the Calabrian down into the middle Pliocene is shown.
- TROELSEN, J. C. Studies on Ceratobuliminidae (Foraminifera).—*Medd. fra Dansk Geol. Forening*, Band 12, Jan. 1954, pp. 448-477, pls. 10, 11, text figs. 1-3.—Revision of the family, in which are retained the genera *Ceratobulimina*, *Lamarckina*, *Epistomina*, and *Epistominoides* only. The structure of these 4 genera and certain others is studied. *Alliatina* n. gen. (genotype *Cushmanella excentrica* di Napoli Alliatina) and 2 new species.
- Paleocaen nord for Mariager fjord.—*Medd. fra Dansk Geol. Forening*, Band 12, Jan. 1954, pp. 479, 480.—Six Paleocene species listed.

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